MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

BLANFORD, H. F. *On the Cretaceous and other Rocks of the* SOUTH ARCOT AND TRICHINOPOLY DISTRICTS, MADRAS.

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VOL. IV.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA
IN COUNCIL,

UNDER THE DIRECTION OF

THOMAS OLDHAM, LL. D.,

Fellow of the Royal and Geological Societies of London; Member of the Royal Irish Academy; Hon. Mem. of the Leop-Carol. Academy of Sciences; of the Isis, Dresden, &c. &c.

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CONTENTS.

NOTICE.

THE following report on a portion of the district of Trichinopoly, and adjoining areas, in the Madras Presidency, has been drawn up by Mr. H. F. Blanford, who had charge of the party of the Geological Survey by whom that country was examined. The map, which accompanies it, is extracted (with a few alterations) from a map of the Trichinopoly district on the scale of one-half inch to the mile, published by the Madras Government—1854; the best map which was available.

The operations of the Geological Survey of India were extended to the Madras Presidency in the beginning of 1857. I had determined to take up first the richly fossiliferous districts of Trichinopoly and Pondicherry, with a view to establishing, if possible, their relations to the rock systems of Bengal. But the season did not permit of the examination of the lower country being commenced at once: and during the hot and rainy months of that year, the Nilghiris were visited. As soon, however, as the change of season permitted, the examination of those districts, in which rocks representative of the Cretaceous formation of Europe were already known to exist from the valuable collections of Messrs. Kaye and Cunliffe, and the admirable description of Professor E. Forbes, was undertaken; and was subsequently carried on without further interruption than was caused by the seasons, until completed towards the close of 1860. During this investigation very extensive and valuable collections of fossils were made; and figures and descriptions of one important group of these, the Nautiloid Cephalopoda, have been already published.*

* Palæontologia Indica, Ser. I.

In issuing a very detailed report, such as the present, it seems desirable to draw attention to the essential difference which characterizes the labours of the Geological Survey of India in different districts: a difference fully exemplified in the nature and amount of detail of the several reports published in these Memoirs. In some cases, a complicated structure, and richly fossiliferous rocks may occur in districts of which topographical maps exist on such a scale as will admit of a large amount of details being recorded with accuracy: in other cases either the merest sketch, or perhaps no map whatever, can be procured. And we have more than once been compelled to construct as rapidly as possible such a topographical sketch as could be carried on without serious delay in the field, and as would suffice to indicate rather than record the Geological observations. Of these two cases, the districts of the Nerbudda mapped topographically as well as geologically by Mr. Jos. G. Medlicott on the one hand; and the Raniganj Coal-Field and the Cretaceous district now published, on the other hand, may serve as fitting examples.

In the one case, no further expenditure of time was permitted, than sufficed to obtain a general knowledge of the main features of the structure of the district; while in the other the fullest and most detailed investigation was given, and such detailed maps and reports as the following are the result. If we consider merely the area examined, as compared with the time devoted to it, the rate of progress in the one case was not one-fiftieth of that in the other.

In justice, therefore, to the writers of the several reports in these Memoirs, this essential difference ought to be borne in mind, as showing that the sketchy outline of general effects in the one case and the minute and careful working out of the details of the picture in the other, are simply the unavoidable consequence of the different circumstances under which they were placed.

In the map and report now published, no attempt has been made to rectify or alter the orthography of the several names of places as given on the original map, however confused and erroneous these were. Any attempt at change in so small a district would only add to the confusion already existing.

THOMAS OLDHAM.

Calcutta, April 1862.

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GEOLOGICAL SURVEY OF INDIA.

ERRATA.

Page	83	note.	*for*	surpula	*read*	serpula.
„	183	line 13.	„	Ninum	„	Nerium.
„	187	lines 6 and 9 from bottom	„	Fig. 15	„	Fig. 16.

I desire to take this public opportunity of correcting an error, into which I regret much I was led by a mistaken impression which I received in conversation. At page 198, Vol. III. of these Memoirs, I have stated that Mr. Rupert Jones had identified the Mangali crustaceans, as *Estheria minuta*. This was not the fact, as will appear more fully in Mr. Jones' own papers.

T. OLDHAM.

Science,* wherein he gave a general resumé of the results of his investigations up to the date of publication. In this paper, Mr. Kaye describes the limestone beds at Sudarampet and their topographical position

* In this paper Mr. Kaye mentions some letters which had appeared shortly before in the Madras *Spectator* Newspaper. These I have not seen, having been unable to procure a file of the Newspaper of that date, nor have I been able to learn with any certainty who was their author. From the way in which Mr. Kaye speaks of them, and from the fact that they appeared, while he was engaged in prosecuting his researches on the spot, I think it most probable that they were from his pen, or at all events that he furnished the materials.

between the sandstones of Trivicary, containing silicified tree stems, and the similar sandstones, which form the Red Hills at Oosatary. He describes a few of the fossils, of which he gives three plates of illustrations, and from the examination of which he infers the limestones to be of Cretaceous date, and contemporaneous with the Chalk and Green-sand of Europe. With regard to the Trichinopoly beds, Mr. Kaye enunciates no decided opinion, but infers "an analogy between the two formations, which further research is required to demonstrate."

Captain Newbold, 1840.

In the previous number of the Madras Journal,* Captain, then Lieutenant Newbold, had suggested that the fossiliferous beds of Pondicherry probably extend into the talook† of Verdachellum, which lies between the Pondicherry district and that of Trichinopoly, but Mr. Kaye remarks that he had not then obtained any evidence of the fact.

Messrs. Kaye and Cunliffe, 1842.

During the subsequent year Mr. Kaye, in conjunction with Mr. Cunliffe, continued his researches, and added to his collections, and in 1842, sent a notice of these to the Geological Society of London,‡ which was published in their Proceedings for that year. In this paper Mr. Kaye describes the Cretaceous rocks of Verdachellum, which he had visited in the interim, as well as those of Pondicherry and Trichinopoly. The latter he had not visited, but he had obtained a series of fossils from the limestone at Garudamungalum, and these, together with his collections from Verdachellum and Trichinopoly, were presented by him to the Society, and subsequently described by Sir Philip Egerton and Professor Edward Forbes. The recent marine deposit upon which Pondicherry stands, and which has been since proved to extend at intervals along a large portion of the Eastern Coast, is also noticed by Mr. Kaye.

* Madras Journal, April-June, 1840, No. 27, page 249.

† In the Madras Presidency, the sub-divisions of districts or collectorates are called *talooks*.

‡ Proc. Geological Society, June 29th, 1842, Vol. III. p. 792.

Mr. Kaye, 1842.

Mr. Kaye's paper in the Madras Journal was re-published in the Calcutta Journal of Natural History in 1842, accompanied by a supplementary paper containing an account of further investigations, and also by a brief description of some of the fossils from the pen of Dr. McClelland.*

Dr. McClelland, 1842.

The fossils noticed are however few in number, and the author does not put forward any opinion respecting their geological age beyond what may be inferred from the (probably erroneous) identification of certain of them with Nummulitic species.

Fossils described by Sir P. Egerton, 1844.

Sir Philip Egerton's description† of the fish remains in Mr. Kaye's collection was published in 1844. The general result arrived at was that the Pondicherry beds must be undoubtedly referred to the Cretaceous period, but that they belong rather to the Upper than to the Lower or Neocomian division of the group; a point upon which he differs from Professor Forbes, whose opinion was founded on the study of the invertebrate portion of the collections.

Fossils described by E. Forbes, 1844-7.

The valuable Memoir of Professor Forbes on the fossil invertebrata of Mr. Kaye's and Mr. Cunliffe's collections, with the addition of a collection made by the Revd. W. H. Egerton, did not appear until 1847,‡ but a brief report communicating the principal results arrived at by its author was read before the Geological Society in January 1844,§ and published in their proceedings for that year. These publications, together with that of Sir Philip Egerton just noticed, form the most important contributions to our knowledge of this part of India that have yet appeared, and indeed from the date of their appearance up

* Cal. Jour. Nat. His. Vol. II., pp. 225—244.

† Proc. Geological Society, 17th April 1844, Vol. IV., p. 381; also Quarterly Journal Geological Society, Vol. I., p. 164.

‡ Transactions Geological Society, Vol. VII., p. 97.

§ Proc. Geological Society, 31st January 1844, Vol. IV., p. 325; also Quarterly Journal Geological Society, Vol. I., p. 79.

to the present time, but little has been added to the facts they contain, however subsequent authors may have differed from Professor Forbes in the conclusions to be drawn therefrom.

The following remarks, extracted from Professor Forbes's report, and quoted *in extenso*, will best express the opinions of that eminent author.

His conclusions.

"*1st.*—The three deposits, *viz.* Pondicherry, Verdachellum, and Trinconopoly, described by Mr. Kaye, are *Cretaceous*, inasmuch as there are characteristic known Cretaceous fossils in the collections from all of them, whilst no fossils of any other system occur. The nearest allies of the majority of the new species are Cretaceous; and among the genera and sub-genera are many which, as far as we know, are confined to, or have their chief development in, the Cretaceous system. The three deposits are connected with each other zoologically by the associations of certain species common to two of them, with others found in the third.

2nd.—Two of the three deposits, *viz.* Verdachellum and Trinconopoly, are of a different epoch of the Cretaceous era from the third, Pondicherry. The two former have several species in common, (and those species among the most prolific in individuals), which are not found in the third. In them are found almost all the species identical with European forms. In several of the genera, of which there are many species, the forms are altogether distinct; although, judging from the evidence afforded by mineral character and association of species, the conditions of depth and sea bottom at the time of the deposition of the strata seem to have been the same. The difference therefore must have depended on a representation of species by species *in time* and not *in depth.*

3rd.—The beds, apparently contemporaneous, *viz.* Trinconopoly and Verdachellum, may be regarded as equivalent to the Upper green-sand and Gault, the European species they include being either characteristic Upper green-sand and Gault forms, or else such as occur in those strata. The new species they contain are either closely allied to known Upper green-sand or Gault species, or peculiar to the Indian beds.

4th.—The Pondicherry deposit may be regarded as belonging to the lowest part of the Cretaceous system. In it almost all the fossils are new. Such as are analogous to known species, are allied to fossils of the Lower green-sand of English Geologists and Neocomian of the French. In the genus most developed in this deposit, *viz.* Ammonites, three-fourths of the species belong to those sub-genera, specially characteristic of the "Lower Neocomian" of the Mediterranean basin, whilst of the remainder, as many representatives of Oolitic fossils occur as of Upper green-sand. The resemblance between the Ammonites of this part of the collection, and those of Castellane in the South of France, is very remarkable, though the specific identity of any of them is doubtful. Having seen no account of the Conchifera of the Castellane beds,* I cannot say how far the analogy is borne out among the bivalve Mollusca among the Indian species, of which there are many very peculiar forms."

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* The 3rd Volume of the *Paléontologie Française* of M. D. Orbigny, containing the Conchifera of the Cretaceous rocks of France, was not completed until 1847, three years after the publication of Professor Forbes' paper here quoted. It was commenced in 1843.

The remaining portion of this Report which treats of abstract palæontological questions, and does not therefore belong, strictly speaking, to the history of the subject before us, need not be quoted here. Until the palæontological collections of the Geological Survey of India have been worked out, and the generalizations of Professor Forbes have been re-tested by the large additions made during the present survey, it would be premature to offer any opinion of their accuracy.

M. E. Chevalier, 1836-44.

Previously to the publication of the papers above quoted, the fossiliferous beds of Pondicherry had attracted the attention of M. E. Chevalier, who visited Pondicherry in the French exploring vessel *La Bonite* in the year 1836 or 1837. The Report of M. Chevalier's observations was not published, however, until 1844,* and precedence must therefore be given to the works of Mr. Kaye already cited. I have not been able to obtain a copy of M. Chevalier's Work, but as quoted by M. D'Archiac, he does not appear to have done more than confirm the existence near Pondicherry of beds of the *Cretaceous* epoch.

Fossils figured by M. D'Orbigny, 1847.

In 1847, shortly previous to the appearance of Professor Forbes's Memoir, M. D'Orbigny gave in the Geology of the voyage of the *Astrolabe*† figures of several species of the Pondicherry fossils, the originals of which had been sent to France by M. Fontanier some years before. From the examination of these, M. D'Orbigny drew a conclusion, differing from that arrived at by Professor Forbes, whose labors had been communicated to him.‡ He places the Pondicherry rocks in his *étage Turonien*, the English equivalent of which he states to be the Lower Chalk of Mantell, and considers them to be also

His opinions.

* *Voyage autour de la monde de la corvette la Bonite*, 1836-37, Géologie et Mineralogie, page 349. Paris 1844.

† *Voyage au Pole Sud et dans l'Océanie.* Géologie. *Pl.* 4—8.

‡ *Bulletin de la Société Géologique de la France.* 2me Serie, Tome 4me, page 507, Séance du 1 Mars 1847.

contemporaneous with certain beds in Java, and with others in the Island of Quiriquina in the South of Chili.*

On a re-examination of the fossils, M. D'Orbigny altered his opinion, and in his subsequent work, the *Prodrome de Paléontologie*,† he ranges the whole of the Pondicherry fossils, with the species of which he makes sad havoc, in the *étage Sénonien* or Upper Chalk "*composè hétérogéne*" (to quote the words of M. D'Archiac)‡ "*mal circonscrit dans le temps et l'espace, et dans lequel l'auteur a réuni les dépôts les plus distincts dans la nature,*" a verdict fully borne out, at least in the case of the Pondicherry rocks. M. D'Orbigny makes no mention of the Verdachellum and Trichinopoly deposits, being probably without any original data on which to found an opinion of their age.

M. D'Orbigny, 1850.

M. D'Archiac's§ opinion based on a general review of the published data, is scarcely more happy than that of M. D'Orbigny, and appears to betray a rashness of assumption, unusual with that excellent author. He finds it difficult to believe that in "*la petite partie de l'Inde,*" comprised between Pondicherry and Trichinopoly, representatives of the Neocomian and Gault of Europe should co-exist, and is inclined to refer the entire series to the latter epoch, a solution with which he considers the generic relations of the fossils perfectly compatible. He closes, however, with the remark that further local investigation appears to be necessary in order to decide the question.

M. D'Archiac.

In 1854, Dr. Carter's Summary of Indian Geology, containing a short notice of the Trichinopoly and Pondicherry rocks, appeared in the Journal of the Bombay Branch

Dr. Carter, 1854.

* The synchronism of the Chili and Pondicherry beds appears to be supported to some extent by Professor Forbes. He identified *Baculites vagina*, a common Pondicherry fossil, in the collection brought to England by Mr. Darwin. Geology of South America, p. 126, Pl. V. fig. 3.

† Prodrome de Paléontologie, 1850, Vol. II., pp. 211, 213, &c.

‡ Histoire des Progrés de la Géologie, 1853, Tome V., p. 420.

§ *Ibid*, pp. 420-21.

of the Asiatic Society,* Dr. Carter had never visited the Cretaceous rocks of Southern India, nor does he publish any new data from other sources; his remarks are, as in the case of M. D'Archiac, those of a reviewer, who draws his conclusions from the data furnished by others.

Mr. Brooke Cunliffe's Collection, 1854.

Nothing further was added to our knowledge until 1857, but in the meantime, in 1854, Mr. Brooke Cunliffe had, by means of his trained native collectors, obtained a large series of fossils from a hitherto unexplored locality intermediate between the original Trichinopoly and Verdachellum fossiliferous sites. He most liberally placed these at the disposal of Mr. Oldham, who visited Madras in the latter part of 1856, and they proved on examination to consist almost entirely of new species of Cephalopoda. An erroneous list† of these, drawn up by myself, was published in a paper read by Mr. Oldham before the Asiatic Society of Bengal in 1858.‡ The described species in this collection were all identical with species previously obtained from Pondicherry, or from the rocks of Cretaceous age in Europe, and the collection, as a whole, indicated an admixture of Neocomian and Upper Cretaceous forms with a decided preponderance of the latter. Dr. A. Hunter of Madras, about this time also procured a series of specimens from these beds, and figured a few of the species in the Indian Journal of Art and Science,§ accompanied by a short popular paper descriptive of the Geology of the country, in which however many mistaken views were put forward. Dr. Hunter had not personally visited the locality in question.

Dr. A. Hunter, 1857-8.

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* Vol. V., page 179; also "Geological Papers on Western India," page 696.

† The list was erroneous partly from mistaken identification of the species, but principally, so far as referring to Ootatoor fossils, from a number of Verdachellum and Pondicherry specimens having been accidently intermixed. The Trichinopoly part of the collection consisted almost exclusively of Cephalopoda. The fossils were stated to be from Ootatoor, but were in reality from near the village of Odium, 11 miles to the North-east of that place.

‡ Journal of the Asiatic Society, Bengal, 1858. Proceed. p. 117.

§ Indian Journal of Art and Science, Nos. 2, 3, and 4.

Revd. Dr. Muzzy, 1857.

In 1857, a paper by the Revd. Dr. Muzzy on the Geology of the Trichinopoly district appeared in the Madras Journal,* forming a valuable contribution to our knowledge of this important but little known district. It contains the results of his observations made while on a missionary tour through the Southern part of the district, and describes with much accuracy the more striking geological features of the country he visited. In it, Dr. Muzzy mentions the discovery of Crustacean remains in great abundance in the gypsiferous clay near Ootatoor as well as of Belemnites, Ammonites, Echinidæ and other fossils; but there is good reason to believe that the first and last of these were the small septaria-like concretions, which abound in these beds, and frequently assume forms which might well deceive any one unpractised in the determination of fossil remains. The Ammonites, Turrilites, and Belemnites are undoubtedly of real occurrence, the last being especially abundant. Dr. Muzzy also describes the prominent ridge of limestone occurring at Garudamungalum, from which Mr. Kaye's "Trichinopoly" fossils had been obtained, and notices its extension to the South as far as the village of Palambaddy, which proves to be the real limit of the Cretaceous rocks in this direction. Dr. Muzzy contributed another notice of the Geology of the Trichinopoly district in his remarks on Mr. Greenough's Geological Map of India, printed by order of Government in 1857, but it contains no new matter of importance, and is almost a verbatim re-production of the paper above quoted.

Mr. Adolphe Schlagintweit, 1856-7.

The late Mr. Adolphe Schlagintweit also paid a brief visit to the known localities of the Cretaceous rocks in the early part of 1856, and published a brief notice of his observations, which was re-printed in the 2nd number of the Journal of Asiatic Society, Bengal, for 1857.† Except the

* Madras Jour. Lit. and Science. New Series, Vol. I., page 90.

† Journal Asiatic Society, Bengal—Vol. XXVI., page 109.

important discovery of the remains of a gigantic Saurian, supposed to be an *Iguanodon,* near Ootatoor, there is but little referring to the Cretaceous rocks in Mr. Schlagintweit's paper that had not been noticed by previous observers. The statement that the deposits of Pondicherry, Verdachellum, and Trichinopoly are continuous, and characterized by the same fossils, is indeed erroneous, but as will be seen by the accompanying map, the strike and dip of the rocks is so uniform, as very naturally to lead to the above conclusion on a mere cursory survey, and the general aspect of the fossils, which alone could be noted by a person making a rapid journey, is also sufficiently uniform to explain Mr. Schlagintweit's mistake.

Summary of the preceding.

To sum up briefly the principal results of the labors of our predecessors. To Messrs. Kaye and Cunliffe, as workers in the field, and to Professor Edward Forbes and Sir Philip Egerton at home, must be attributed the merit of having first established the existence of rocks of Cretaceous age in Southern India, and of having accumulated, and worked out, the most valuable mass of fossil evidence bearing thereon, that has hitherto been placed on record. To the scientific skill and acumen of Professor Forbes, we are further indebted for pointing out the characteristic differences of the fauna of the Verdachellum and Trichinopoly (Garudamungalum) beds on the one hand, and the Pondicherry beds on the other; and of assigning to each its approximate position in the scale of geological sequence; a position, which the additional evidence lately obtained on the spot, has only tended to confirm.

We have seen that the conclusions of this eminent Palæontologist have been called in question by the late M. D'Orbigny and M. D'Archiac, both authorities of well-founded celebrity; and it is in no spirit of disparagement of these gentlemen, that we pronounce the present confirmation of Professor Forbes's view to afford a new proof, were such

wanting, of the profound knowledge and accurate judgment for which he was so justly distinguished. But while we fully acknowledge the high claims of Professor Edward Forbes to stand first in the ranks of those who have labored to elucidate the Geology of this part of India, it is due to Messrs. Kaye and Cunliffe to state, that to their spontaneous ardour in the cause of science and to their labors prosecuted as a relaxation in the midst of onerous official duties, we are indebted for the material from which Professor Forbes's conclusions were drawn. The former of these gentlemen did not live to see the first results of his labors given to the world. He died while the report of Professor Forbes was passing through the press : and we can only regret with the Officers of the Society, of which he was so promising a member, that Indian science was deprived thus early of one who had shown so much energy in its advancement.

Mr. Cunliffe continued, as we have stated, to prosecute his researches in the Trichinopoly district, (until, by change of residence, he was removed from the scene of his labors,) and amassed a most valuable collection of fossil remains from a locality till then unexplored, which he liberally placed at the disposal of the Survey, and the description of which was only postponed, because it was then in contemplation to undertake the systematic examination of the district of which the present memoir is the result. The probable importance of such a survey and the promising richness of the fauna, had been further proved by the continued labors of Mr. Cunliffe, Dr. Muzzy, and those other gentlemen, whose names we have above recorded, and although it cannot be doubted that the fossil riches of the country, more especially of the Trichinopoly district, have been by no means exhausted, it is hoped that the present description may place the knowledge of the geological structure of the country on such a footing, that all future discoveries may be assigned readily to their proper place.

Before closing the present sketch, I would say a few words on a group

of rocks associated with the Cretaceous series of the Carnatic, concerning which various and conflicting opinions have been put forward by different observers. These beds consisting of ferruginous sandstones, which occasionally contain fossil wood but are almost without any trace of other organic remains, occur in patches of variable extent in several parts of the district. Their occurrence at Trivicary near Pondicherry was noticed in 1810 by Captain J. Warren,* and in 1840, by Mr. Kaye in his paper in the Madras Journal already cited, and he speaks of the silicified wood, which there occurs in unusual abundance, as well known to the public. Both in this paper and in his subsequent notices, published in the Proceedings and Journal of the Geological Society, he leaves the question of the Geological relations of the Trivicary beds to the Cretaceous rocks undecided, merely describing their topographical position to the West of the latter, and the occurrence of very similar beds, forming the little plateau known as the Red Hills, on the Eastern boundary of the same rocks. He suggests indeed that the Red Hills "may be a continuation of the Trivicary beds," in which case, he remarks, "it is evident that the lime-stone rests upon a basin or depression of the red sand," a deduction which would, however, only be true, if by the term continuation we understand *actual* unbroken continuity. He evidently does not contemplate the true state of the case as afterwards made out by Captain Newbold, *viz.*, that the Red Hills and the Trivicary beds are portions of a set of beds *originally* continuous, and now isolated by the denudation which laid bare the underlying Cretaceous rocks.

Tree-bearing sandstones of Trivicary, &c.

Captain Warren 1810.
Mr. Kaye 1840.

Captain Newbold, 1845.

Captain Newbold† who, by his assiduous observation, while marching rapidly in various directions across the Peninsula, has done so much for the Geology of this part of

* Asiatic Researches, Vol. XI., p. 1, with a Plate.

† Journal Asiatic Society, Bengal—Vol. XIV., page 759.

India, not only established the true position of the sandstones of Trivicary and the "Red Hills," but also discovered beds of similar lithologic character at Verdachellum, and at various points in Nellore, and in the neighborhood of Madras, all of which he identified with the sandstones of Trivicary. At Verdachellum he found fossil wood similar to that at Trivicary, and noticing the position of the sandstones, as overlying the fossiliferous limestone, he expresses his belief that they were once continuous with the beds of Trivicary.

Mr. Adolphe Schlagintweit, 1857.

Mr. Adolphe Schlagintweit,* on the other hand, probably unacquainted with Captain Newbold's writings on the subject, describes the Trivicary beds as underlying the Cretaceous rocks of Pondicherry, and further identifies them with the great sandstone formation of Central India, which he refers to the Oolitic series. A short paper, in refutation of this view, was contributed by myself to the Madras Journal in the early part of 1859.†

Dr. Carter, 1854.

Equally erroneous is the view promulgated by Dr. Carter in his *Geological Summary* before noticed. Dr. Carter classes the Trivicary beds with the ossiferous conglomerates of Perim Island, the Nerbudda, &c., as Miocene; while he regards the sandstones of the Red Hills as Pliocene. Dr. Carter had never visited the spot, or he could scarcely have fallen into the error of considering the sandstones of the two localities as distinct formations.

Of the other rocks, which I shall have occasion to refer to in the following pages, the sub-recent coast deposits have been noticed by Mr. Kaye and Captain Newbold in the papers above quoted. The gneiss rocks, with their associated granite veins, have also been described by various observers.

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* Journal Asiatic Society, Bengal—Vol. XXVI., page 109.

† Madras Journal, Literature and Science, New Series—Vol. IV., page 47.

It now only remains to mention those gentlemen who have been associated with me in the present survey, and to ascribe to each that portion of the work to which he has mainly devoted himself. The Survey commenced in January 1858, and during the working season of that year, Messrs. Charles Oldham, King, and Geoghegan, with myself, mapped a large portion of the sedimentary rocks to the North of the Vellaur, and in part the boundary of the Cretaceous rocks in Trichinopoly. A series of fossils was also collected from all the localities visited. This first season was brought to an abrupt close at the latter end of April, by the sad loss of Mr. Geoghegan, who received a sun-stroke while engaged in his duties, and expired in the course of a few hours. Mr. Geoghegan had joined the Survey about a twelvemonth previously, and had been our companion in the Survey of the Nilghiris and in the Trichinopoly district up to the date of his untimely death.

Geological Survey of 1858.

In the month of June, Mr. Willson assumed temporary charge of the party, (while I visited Calcutta, in order to commence the examination of the fossils we had collected,) and in conjunction with Messrs. Oldham and King he mapped the alluvium to the North of the Coleroon, between the Vellaur and Lalgoody, and the granitic area of Thutchuncoorchy. I returned to Madras in December with Mr. Bruce Foote, who had recently joined the department, and undertook the detailed survey of the Cretaceous rocks of Trichinopoly. Messrs. King and Foote continued to examine and map the alluvium to the West of Trichinopoly, and subsequently that of the Vellaur, the sands of the Coast, and the whole of the country to the South of the Cauvery included in Sheet 79 of the Atlas Map. Mr. Charles Oldham joined us in March, and in the following months collected a most extensive series of fossils. My brother, Mr. W. T. Blanford, at the close of the working season in Bengal, passed a couple of months in Trichinopoly, and mapped the crystalline rocks to the West and

Season of 1859.

South of the Cretaceous basin from Volcondah to the Coleroon, with a portion of the alluvial boundary that had been left unfinished the preceding year; and finally the season of 1860 was devoted by Messrs. King and Foote to the continuation of their survey of the gneiss country,

Season of 1860.

and by myself to the completion of the Cretaceous and associated rocks, and to a general review of the surrounding country.

Object of present memoir.

It may possibly seem premature to publish a Geological description of the country, in anticipation of, and consequently unsupported by, the important Palæontological evidence, which the examination of the fossil collections will undoubtedly afford. These collections are, however, numerically so extensive, and contain so large a proportion of entirely new species, that a careful and detailed examination and comparison with known forms, such as alone could be of real value for the purpose of science, will probably require some years for its accomplishment; and it was therefore desirable to publish at once such Geological facts as have been well established, leaving all Palæontological details and the general considerations founded thereon until a future period. This course can be the more easily adopted, inasmuch as the main facts here put forward are founded on *stratigraphical evidence*, on observations made in the field; and such references to Palæontological facts as occasionally occur, are strictly subordinate to a Geognostic treatment of the subject. In the examination of a series of beds, so rich in fossil remains as those of Trichinopoly and South Arcot, it would, of course, be impossible entirely to neglect Palæontological evidence, and indeed the absolute necessity of some acquaintance with the new fossil forms, which presented themselves during the progress of the survey, has been throughout experienced, and has much retarded the progress of the field work. It would be equally absurd to attempt to distinguish the subjects of study so far as to omit all reference to fossils in compiling a Geological

description of the country surveyed. The Palæontological and Geognostic questions, which are solved by the study of these organic remains, may however be easily kept distinct, and we may regard the fossils either as mere indices for the identification of rocks not visibly continuous, in which point of view a Geological Surveyor has chiefly to deal with them, or we may study them in their Biologic aspect as indicating the conditions of a deposit and affording evidence of the distribution, succession, and other relations of beings in past time,—questions which pertain to the province of the Naturalist and the Theoretical Geologist. In the following pages, I have therefore refrained from entering into Palæontological questions, except in one case, beyond the mere enumeration of such well identified genera or species as have been met with in different localities, reserving all else for a future publication. The exception I refer to, is the question of relative age of the Pondicherry beds as compared with those of Trichinopoly. In this case, in the absence of any sufficient stratigraphic evidence, we are compelled to fall back on that of the fossils; but the task is here rendered easy by the circumstance, that the fauna of the former beds has been already well investigated by one of the first Palæontologists of modern times, whose conclusions, as regard these beds, have received unexpected confirmation in the clearing up of those discrepancies which he and others noticed, and which led Sir P. Egerton, and in part also, M. D'Orbigny, to doubt the accuracy of his conclusions.

CHAPTER II.—*General description of country.*

Physical features of the Carnatic.

THE tract of country, the Geology of which is described in the following pages, is a portion of the great plain which extends along the East Coast of Southern India between the Bay of Bengal and the hill country of the interior. With reference to its physical position, it is termed the Payen Ghât, or "country below the Ghâts," and is included in the political division of the middle Carnatic.

Eastern Ghâts.

It will be seen on reference to the map of India* that the great escarpment known as the Eastern Ghâts, which bounds the elevated plateau of Hyderabad and Mysore, trends off in a South-westerly direction from the neighbourhood of Vellore, and finally terminates in the Nilghiris.† It must be remarked that although the term escarpment is here, as elsewhere, frequently used in speaking of the Eastern Ghâts, it is only admissible, if we regard them as a great physical feature of the Peninsula, and as indicating the rapid rise of the country which divides the plains of the Eastern Coast from the plateaux of the interior, and it must not be inferred that there exists only a single well defined scarp similar to that of the Western Ghâts, along the whole or indeed the greater part of their extent. Their southern portion is either broken into two or more minor escarpments, as in the Baramahal, or lost in the groups of lofty hills which fall away in both directions and conceal the difference in elevation of the tracts of comparatively level country on their opposite flanks. And even where a true escarpment exists, it forms but a small portion of the actual total rise of the country. The Eastern Ghâts are further interrupted by the valleys of all the principal rivers of the

* The Indian Atlas maps on the scale of 4 miles to the inch give a very clear idea of the minor physical features of the country. Sheets 60, 61, 62, 78, 79, and 80 exhibit the whole of the country here briefly alluded to.

† See Report on Geology of the Nilghiris. Memoirs, Geological Survey of India. Vol. I., page 211.

country, such as the Cauvery, the Punniar, the Palar, and the Panar, which drain the central plateau from within a few miles of the Western Ghâts, and, except in the case of the first named river, debouch into the plains through broad depressions in the general surface of the country, rather than through gorges cut by their own attrition in the rocks of the plateau.

Country below the Ghâts.

Again the country below the Ghâts is by no means an unbroken plain : several hill groups, more or less isolated, and some of them of great elevation, occupy the country to the South-east, and carry on the line of the uplands parallel with the Coast as far South as the Cauvery Valley, which, together with the gap of Palghat to the South of the Nilgiris, constitutes a narrow strip of low country stretching across the entire Peninsula and separating the Nilgiris and the outlying hill country of Trichinopoly and Salem on the North, from the Anamullies and similar hill clusters of Madura and Tinevelly on the South. The low country proper, or Payen Ghât, is thus restricted to a tract from 60 to 80 miles in width, which stretches along the Coast from Cape Comorin to the united deltas of the Kistna and the Godavery, beyond which the hills of the Northern Circars advance to the Coast, and range northward to the Chilka Lake and the delta of the Mahanuddy.

No disturbance of country in later Geologic times.

We shall see in the course of the following pages, that there is strong reason to believe that the main features of this physical configuration have existed unaltered through a long geological period : that, since the commencement of the Cretaceous epoch, (the earliest of which in the country hitherto surveyed we have met with any *undoubted* Geological records) no disturbance of any magnitude or extent has remodelled or effaced the main orographical features.* While the oldest rocks of

* Mr. Adolphe Schlagintweit in the paper previously referred to enunciated a similar opinion. The note to my report on the Nilghiris (*Memoirs Geological Survey of India, Vol. I., p.* 233) was founded on erroneous and premature conclusions as to the disturbances affecting the older Cretaceous rocks of Trichinopoly.

Trichinopoly have suffered some slight faulting, but to such an extent only as could affect but little the general surface of the country, all except these oldest are quite undisturbed ; and the oldest rocks of Pondicherry which, judging from their fossil remains, are of even greater age than the oldest which occur in Trichinopoly, (with the exception possibly of the plant beds) lie undisturbed, and unaltered, and are at a scarcely greater angle of inclination than that of the present sea-bottom of the Bay.

But frequent changes of level.

We shall see further that a great portion of the Payen Ghât has suffered repeated depressions and re-elevations, and that from the hills, or the still unsubmerged area at their foot, have been derived the materials, which, during the oft-repeated oscillations of the country, have accumulated in the thick beds of conglomerate, sand, and clay, which now occupy the Eastern portion of our area, and entomb in vast numbers the fossil remains of the faunas and floras of several successive periods.

Extent of country described.

That part of the Payen Ghât, which forms especially the subject of the present memoir, comprises portions of the district of Tanjore, Trichinopoly, and South Arcot, and is included in Sheet 79 of the Indian Atlas Maps, the North and South limits of which sheet are also those of the present Survey. This area extends from the parallel of latitude 12 miles North of Pondicherry to that 4 miles South of Negapatam in Tanjore, and is bounded on the East by the Sea coast, and on the West by two of the Hill groups already mentioned, called respectively the Kalrymullays and the Pucha-mullays ; the former being situated to the North in the Salem district, the latter to the South in that of Trichinopoly.

Hill groups.

These two groups, together with the Shevaroys and Tainandamullays and Chitairy Hills on the North and North-west, and the Collamullays and Pythoormullays on the South-west may be regarded as but portions of one great group separated

by narrow gorges or passes, the level of which is but little above that of the surrounding plains. The principal of these is the pass of Ahtoor, running East and West between that place and Salem, and separating the Shevaroys and the Chitairy and Kalry Hills on the North, from the Collamullays and Puchamullays on the South.

The chief rivers.

The three principal rivers of our district are the Cauvery, with its principal arm the Coleroon, to the South and South-east of the hill country: the Vellaur in the centre: and the Puniar to the North. The smaller streams draining the hills and the low country at their Eastern foot are: the Ariancoopum, West of Pondicherry, entering the Bay immediately to the South of that place; the Guddalum and the Cuddalore River which enter the sea at Fort St. David: the Munny Mookta, Ellayaur and Chinnaur draining the Eastern flank of the hills, and uniting lower down with the main stream of the Vellaur: and the Murdayaur, Koolayaur, and Dyaur which drain the country to the South of the Vellaur water-shed, and fall into the Cauvery and Coleroon.

No deltas now forming.

No deltas are now forming at the mouth of any of these rivers. The large quantities of sediment carried down in their waters during freshets are swept away by the strong current which sets up the Coast, and the long even line of sandy Coast which stretches along the sea-board of the Peninsula, is unbroken by the encroachment of any modern deposit on the surf-bounded waters of the Bay. The alluvial deposits of a by-gone epoch extending inland to the Westward, are now upraised from 20 to 30 feet above the reach of the highest floods, and the great rivers flow for several miles through plains of an old alluvium now in course of destruction; and in obedience to the same law of gravitation which determined its formation, being denuded by the streams that partly formed it, and carried down to be deposited anew in the great reservoirs of the Ocean. Along the Coast this formation continues

Old alluvial deposits.

without a break from Pondicherry to Point Calimere, beyond the Southern limits of our map, and stretches inland in three principal divisions, corresponding to the principal rivers of our area.

Alluvium of the Puniar valley.

The first of these, that of the Puniar, is about 12 miles across near the Coast, occupying the country between Pondicherry and Cuddalore, and extending inland as far as Tirukovalur. Besides the Puniar, it includes the Ariancoop and the Guddalum, the former flowing along its Northern boundary the latter on its Southern limit, and connected with the main stream of the Puniar by a cross channel some miles inland.

Of the Vellaur valley.

The second, that of the Vellaur,* extends from Cuddalore to the mouth of the Coleroon, and stretches inland to Thittagudi, 44 miles from the Coast. It is a remarkable feature in this alluvial plain, and in that of the Puniar, that they are wider some miles inland than near the Coast, being constricted, so to speak, by a low plateau of red sandstones and laterite, which occupy the Eastern portion of the intervening higher ground, and form low escarpments in the neighbourhood of Pondicherry and Cuddalore. The probable causes of this peculiar feature, and the modern changes in the Physical Geography of the country which, in common with some other facts, it seems to indicate, will be discussed hereafter.

Of the Cauvery valley.

The third division of the alluvial deposit forms the delta of the Cauvery, included in the fertile province of Tanjore and terminating to the South in Point Calimere. The greater part of this delta, like the alluvial plains of the Vellaur and Puniar, is now at a higher level than that of the highest floods. The

* The *Vellaur*, or *White River:* the termination *aur* or *ar*, common to most of the rivers in this part of India, being a corruption of the Tamul word *àrú*, a river. The addition of the word river, in English, is therefore redundant, but is retained in conformity with custom. The same remark applies to the affix, *mullays* or *mullies*, to the names of hills, mullai being the Tamul word for a hill or mountain.

surface is sometimes undulating, and at one spot on the Coast, the alluvium forms a little bank a few feet high, now gradually yielding to the denuding action of the waves.* The recent alluvium, that below the present flood level of the rivers, forms a narrow strip along the course of the main streams, and can scarcely be defined with accuracy, owing to the great works of irrigation which have now converted a large part of the older alluvial tract into a wide spreading paddy swamp.

Higher parts of plains.

The more elevated portion of the low country between the alluvium and the hills, is a gently undulating tract, formed by sedimentary rocks on the East and crystalline rocks (principally gneiss and hornblende schist, with a few granite veins and greenstone dykes) on the West. The country is dry and barren, sometimes rocky, but more frequently covered with the soft black loam, known as "regur" or cotton soil, and with the red ferruginous sand, termed "lal" elsewhere. The distribution of these two soils, and its bearing on the Physical Geography of the country in recent times, is a point of much interest, and will be more fully treated hereafter. It is sufficient for the present to mention that the latter soil prevails in the Eastern part of our area, where it usually bears a tall thick growing jungle of *Euphorbia*, *Melastoma* and various other plants, while the former occupies the country South of the Vellaur between the red soil and the hills, overlying both the sedimentary and crystalline rocks. It is, in fact, continuous with the ancient alluvium of the Vellaur and Cauvery, already described.

Soils.

Country of crystalline rocks.

A few small rocky hills, rarely exceeding 200 feet or 300 feet in height, are dotted at intervals over the country occupied by the crystalline and semi-crystalline rocks, and on some of the larger of these hills are perched the little forts or droogs of the old Poligar Chiefs, the names of which occur so frequently in the history of the wars of the Carnatic.

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* For this fact I am indebted to Messrs. King and Foote's Reports.

This brief sketch of the general features of the country will suffice to explain the geographical relations of the principal rocks, and we may now proceed to describe more at length the igneous and older sedimentary rocks of the district, as regards their classification and mode of occurrence.

Limits of the two classes.

I have already stated that rocks of sedimentary origin occupy the high ground of the Eastern part of our area, the crystalline and semi-crystalline rocks being confined to the hills and low country adjacent. The boundary between these two classes nearly coincides with a straight line drawn from a point on the sea-coast, 10 miles North of Pondicherry, to the village of Tripatoor, 15 miles North of Trichinopoly,* its continuity being, however, broken by the alluvial plains of the Puniar and Vellaur, which extend beyond the limits of the sedimentary rocks, and thus divide the sedimentary area into three divisions, which we may distinguish by the well known names of Pondicherry, Verdachellum, and Trichinopoly respectively. To the South of Tripatoor the boundary is more irregular, and after bending some miles to the Eastward, disappears beneath the delta of the Cauvery. To the South of this river sedimentary rocks re-appear to the West of Tanjore, and occupy a large extent of country. But their extension in this direction is unknown, as they have not been traced beyond the limits of the present map.

Sedimentary rocks.

I have hitherto spoken of the sedimentary rocks in general terms as a single series, but they comprise, in fact, several distinct groups of deposits, resting unconformably on each other, and representing in broken sequence a long Geologic period. As developed in the Trichinopoly area, where they are

* The Cretaceous rocks, as laid down on Mr. Greenough's Map, are altogether too much to the West. Their real position is on the area coloured as Gneiss between that assigned to them and the sea-coast. The ferruginous (Cuddalore) sandstones, and a large part of the alluvial formation, both of them important features of the Geology of this part of the country, are omitted in this map.

best seen and most extensive, these groups are five in number, three of which are undoubtedly of Cretaceous age. Taken in descending order, they may be enumerated as,

In Trichinopoly district.

TERTIARY ? ...	The Cuddalore sandstones ? Exogenous plant remains in Pondicherry.
CRETACEOUS ...	The Arrialoor Group, highly fossiliferous.
	„ Trichinopoly Group, ditto ditto.
	„ Ootatoor Group, ditto ditto.
?	The Ootatoor plant beds: plant remains, other fossils doubtful ?

and to these we may add a very remarkable and interesting formation, the "Coral reef limestone," which occurs at a few points at the base of the Ootatoor Group, apparently formed under somewhat different conditions, but physically associated with it.

The lowest and therefore oldest beds, the "Plant beds," are seen in the neighbourhood of Ootatoor, cropping out irregularly from beneath the base of the Ootatoor Group, and occupying the South-western corner of the sedimentary area. From this point, if we proceed either Eastward across the strike, or North-eastward along the general boundary of the sedimentary rocks, we meet with all the members of the above series successively overlapping each other, and dipping at a low angle with much regularity to the East. The highest group, a mass of coarse, ferruginous grits of unknown thickness, which we have termed the Cuddalore sandstones, occupy a large area to the North-east, including nearly the whole of the Wodiarpolliam talook, and they re-occur in Tanjore to the South of the Cauvery, where they rest immediately on the gneiss. A few outliers of these rocks are scattered here and there over the Cretaceous rocks to the West of the principal formation, and are in general easily recognizable by their coarse grain, their mottled colors, and the universal absence of any fossil remains.

In Verdachellum area.

The Verdachellum area to the North of the Vellaur is of smaller extent, and is occupied mainly by the Cuddalore sandstones, but these beds are rarely exposed, being concealed beneath a great thickness of ferruginous sandy soil, the material of which they have, in a great measure, furnished during subsequent denudation. The upper, or Arrialoor Group, of the Cretaceous rocks is alone exposed to a limited extent to the North and West of Verdachellum, and these beds also, owing to the thick covering of soil, are but little seen, except near the village of Panùr, whence Messrs. Cunliffe and Kaye obtained the Verdachellum fossils of their collections.

Pondicherry area.

The Pondicherry area is almost equally obscure, owing to the absence of sections and the thickness of the soil which conceals the outcrops of the beds. A strip of the Cuddalore sandstones forming as usual a little plateau, and known as the Red Hills, extends along the coast to the North of Pondicherry, and another small outlier, well known to local Geologists from the abundant silicified remains of fossil wood which it has yielded, occurs in the neighbourhood of the village of Trivicary, 13 miles West of Pondicherry. The intermediate area, about 8 miles in width, is occupied by the Cretaceous rocks, which are for the most part nearly horizontal, but owing to the abovementioned causes, are only seen at rare intervals; and were it not that the rocks of Trichinopoly furnish us with a key to their Geology, it would be almost impossible to arrive at a true explanation from the obscure and scanty data obtainable on the spot.

Anomalies in its fauna.

The peculiar mixture of species in Mr. Kaye's collection of Pondicherry fossils was commented upon by Professor Forbes, and although from the preponderance of *Cephalopoda* related to, or identical with Neocomian forms of Europe, he referred the entire fauna to that epoch, he noticed as an anomalous circumstance the existence of species of *Cypræa,* (or Ovulum) *Oliva,* and some other tertiary genera, at so remote a period. So much weight did Sir Philip

Egerton and M. D'Orbigny attach to the Tertiary and Upper Cretaceous aspect of the ichthyous portion of the fauna, that in spite of the counter-evidence afforded by the Neocomian forms of the *Cephalopoda*, they were inclined to assign the Pondicherry beds to a period not earlier than the Upper greensand or Gault; considering that, while, on the one hand, a number of Neocomian species had lived on to a later period than their nearly related congeners of Europe; on the other hand, certain tertiary genera had begun to appear at an earlier period in these tropical seas, to which, at the present day, some of them are exclusively confined. That no one surmised the true state of the case, *viz.* that the fosslis were obtained from two different deposits, is probably due to the resemblance of the two rocks in which the fossils occur, and the knowledge that they were all obtained from within an area of not more than two or three square miles in extent. Indeed, I myself, who had visited the locality, and was aware of the anomalous character of the fauna, had no suspicion of the existence of two sets of beds until the Geology of the Trichinopoly district being worked out, I found that several of the Pondicherry species were especially characteristic of the *highest* or Arrialoor group, while of the *Ammonitoid Cephalopoda* so abundant in the Pondicherry beds, and Neocomian in their affinities, but one or two species occurred in any part of the Trichinopoly series, and these few only in the Ootatoor or *lowest* group. This led me to examine the association of species in specimens of the Pondicherry rocks, and the result strongly confirmed the supposition of the existence of two distinct faunas: a supposition which re-examination of the beds at length finally established.

Explanation.

A detailed description of the locality will be given further on, and it will be sufficient to remark here, that the Arrialoor beds occupy a narrow band of country to the West of the Red Hills, cropping out from beneath the unfossiliferous

Extent of Cretaceous rocks.

grits, of which these Hills are composed, and capping the higher parts of the rolling ground beyond. The country to the North-west of this, and comprising the great portion of the Pondicherry area, is occupied by the older group, for the most part unfossiliferous, but containing one fossiliferous band just where it is overlapped by the Arrialoor group; and hence were derived the fossils of Messrs. Kaye and Cunliffe's collections. That these latter beds are not equivalent to any portion of the Trichinopoly marine series, but are of older date, is a point upon which little doubt can be entertained. It is certain indeed that, as above remarked, some species of *Cephalopoda* are common to the two sets of beds, but not only do these species form a very small percentage of the total number in each fauna, but they are among the least abundant species in each case, while the Geological affinities of the two faunas, taken in the mass, tend in opposite directions: that of the Ootatoor group recalling rather the Gault and Upper greensand forms, while, as remarked by Professor Forbes, that of the Pondicherry beds is decidedly Neocomian. In order to avoid misconception, it will perhaps be best to speak of the Pondicherry beds under a distinct name, which implies no pre-judgment of the question of their age. The 'Valudayur' beds will be convenient for this purpose, the name being taken from the village* near which is the fossiliferous locality alluded to.

In the detailed description of the Cretaceous rocks, to which the following pages are principally devoted, I shall follow a similar course to that adopted in this introductory chapter; commencing with the Trichinopoly district, which is not only the most extensive, but also that in which the different formations are best displayed, and their mutual relations most

* I write this name as it is pronounced by the Natives and by the French, and as it is marked on the Map. The English corruption, Verdoor, is quite unintelligible to the Natives, as I found during my first day's experience of the country, my servants, tents, and baggage going astray in consequence, and leaving me to the hospitalities of a dismantled bungalow.

clearly exhibited ; I shall afterwards describe the contemporaneous rocks of Verdachellum and Pondicherry, and pass to the wide spreading deposits which I have termed " Cuddalore Sandstones."

I shall only make a few brief preliminary remarks on the modern deposits of the river-valleys and of the coasts, and on the crystalline and semi-crystalline rocks, (which have been surveyed almost exclusively by my colleagues Messrs. King and Foote,) viewing them only so far as they are connected with the stratified rocks which form the main subject matter of these pages.

PART II.—DESCRIPTIVE DETAILS.

§ 1.—*Trichinopoly District.*

Little hitherto known.

OF the Geology of Trichinopoly, as indeed of most of the Southern districts of the Peninsula, but little has hitherto been recorded. The researches of Newbold, Malcolmson, Voysey, and most of those earlier Geologists, who have contributed so much valuable information respecting the Central and Northern Provinces of the Madras Presidency, never extended to the more isolated Southern districts,* and Messrs. Kaye and Cunliffe, to whose labors we mainly owe our knowledge of the neighbouring district of South Arcot, restricted their personal investigations to the rocks of that district, and were only able, by availing themselves of the assistance of a non-geological friend, to substantiate the existence in Trichinopoly of rocks of similar age to those which they had examined in person in the neighbourhood of Pondicherry and Verdachellum. With the exception of

* Excepting a narrow strip on the West Coast, which has been described by Captain Newbold and also by General Cullen.

the late Mr. Adolphe Schlagintweit, whose visit was of the briefest, the Revd. Dr. Muzzy of Madura is, so far as I am aware, the only Geologist who has travelled over the country I am about to describe, and his observations, however valuable, were almost necessarily fragmentary, his attention having been directed to the Mineralogy and Petrology of the district, rather than to the elucidation of its Geological structure. The sedimentary rocks of Trichinopoly have thus remained comparatively unknown, and it was by no means anticipated that a detailed survey of the district in question would disclose an extensive series of deposits ranging with but slightly interrupted sequence through the whole of the upper Cretaceous epoch, and abounding in the exuviæ of three successive faunas.

Physical Geography of the Cretaceous period.

The evidence of the Geographical conditions of this portion of Southern India during the Cretaceous period is, indeed, very complete; with the single exception of a dislocation of some of the older beds at one point near Ootatoor, the whole series of the sedimentary rocks rests almost in the original planes of deposition. That the sea in which they were formed was comparatively shallow, there is, as I shall presently show, abundant evidence, both lithological and palæontological, to prove, and in the lofty hills which rise at a short distance from the present edge of the denuded Cretaceous rocks, we have the land which, after making allowance for much denudation, can scarcely have changed greatly in general form, since it towered up from the bosom of the Cretaceous sea. On this land, probably, grew the Zamias and other plants, the remains of which occur so abundantly in the lowest beds of the stratified rocks and hence, or from the corresponding hills in Madura to the South of the Cauvery Valley, was floated the fossil wood which, sometimes sound and intact, sometimes bored through by the Teredo, abounds in certain beds throughout the series. From these and the surrounding hills too, and from a part of the low country at their foot, were derived the sand, clay, and conglomerate of which these Cretaceous rocks are built

up. Isolated bosses and ridges of coral limestone are dotted over the original sea bottom of the area, and round them are banked the deposits of clay and sand with which, at a subsequent period, the sea became charged, and beneath which they are partially or wholly buried.

Crystalline rocks.

In order to ensure a full appreciation of these and similar points, it will be necessary to premise a more detailed description than I have yet given of the country in the immediate vicinity of the Cretaceous rocks; and I shall for this purpose avail myself to some extent of the results of my brother and of my colleagues, Messrs. King and Foote, who have principally devoted their attention to the examination of the Crystalline rocks.

Trichinopoly.

The Crystalline Rocks.—Trichinopoly, the principal Military Station of the Southern division of the Madras Presidency, and the chief town of the district of the same name, is situated at the head of the Cauvery delta near the South bank of that river, and a few miles below the divergence of its two main branches, the Cauvery and the Coleroon. The town is built on gneiss, a large boss of which, crowned with a pagoda, and known as Trichinopoly Rock, rises in the centre of the fort to a height of 236 feet above the sea.

Country to South and South-west.

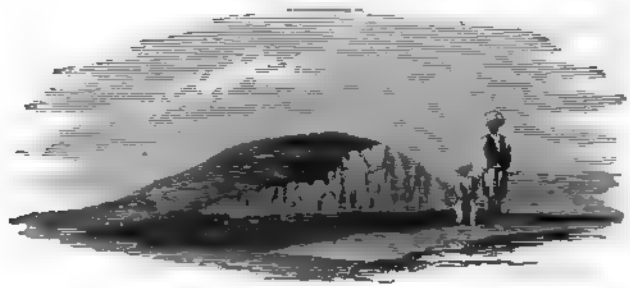
A few similar bosses are scattered at distant intervals over the country to the South, and far to the South-west are seen the Serumullays, one of the great island-like groups of hills, which, as I have already mentioned, occupy the centre and Western half of this part of the Peninsula. These hills, as well as the whole of the intervening country, consist of gneiss and other metamorphic rocks.

To North of the Cauvery.

The alluvial plain of the Cauvery opposite Trichinopoly occurs chiefly to the North of the river, and, including the Island of Seringham, which separates the two main branches of the stream, is not more than from 4 to 6 miles across. Indeed, the strictly fluviatile deposit is somewhat less than this in extent.

A strip about 2 miles broad along the outer or Northern edge consists of a dark argillaceous soil, differing much from the pale sandy loam of the river-banks, and identical with the superficial deposit which, known as regur or cotton soil, extends up to the higher ground and covers a great part of the district. This soil is apparently of distinct and prior origin to the river alluvium, (See Fig. 1, which shows the regur underly-

FIG. 1. SKETCH SHOWING RELATIONS OF REGUR AND ALLUVIUM NEAR PAROOVALAPOOR.



ing the alluvium, near Paroovalapoor, where the latter is very thin); but as this fact was not clearly ascertained until the survey of a great part of the country had been finished, and as, moreover, the scale of the map is such as to preclude the distinct representation of the soils together with the varied features of the older formations, the alluvial boundaries as originally laid down, are shown. The tract, which on the map is colored as alluvium, includes therefore, together with the fluviatile alluvium, so much of the cotton soil as occupies a part of the river valleys, and is of such thickness that the nature of the underlying rock cannot be certainly ascertained. In the case of the Cauvery and its tributaries, the practical discrepancy thus arising is of no great amount; but the great plain which spreads out on the upper course of the Vellaur consists entirely of regur with the exception of narrow strips bordering the principal streams.

Thutchuncoorchy.

Granite.—To the North of Trichinopoly, at a distance of 2 to 3 miles from the North bank of the Coleroon, the Crystalline rocks rise from beneath the alluvial plain with a well marked declivity. A broad band of barren stony ground

marked with conspicuous ridges of bare rock, pink and glittering with abraded quartz and felspar (Orthoclase,) stretches for many miles along the North flank of the alluvial valley; its course, (nearly East and West,) coinciding with that of the river and that of the gneiss folia and bedding, over the whole of the low country between the Collamullays and the hills of Madura. To the Westward this granitic band has been traced* in undiminished breadth as far as Caroor, and there is reason to believe that it extends much further: granite veins are found in the neighbourhood of Coimbatoor; and as the gneiss, with the local structure of which it is intimately connected, pursues the same East and West strike across the Peninsula, as far at least as the Palghât gap, it is not improbable that the granite of Coimbatoor may be a portion of the band I have described.

Its direction,

and extent to the Westward,

To the East of the Madras road it may also be traced as far as any of the Crystalline rocks are exposed, *viz.* to the village of Shuthamungalum, where it disappears beneath the Cretaceous rocks. To the North-east of Samiaveram it rises considerably above the average level of the surrounding country, its highest point, Thutchuncoorchy hill, and a great part of its undulating surface, being probably not less than 300 feet above the level of the Cauvery. This elevated granitic tract is an important feature in connection with the Physical Geography of the Cretaceous rocks. Of the date of the intrusion of the granite we know but little, beyond the fact that it must have been long, probably very long, anterior to the formation of any of the existing local sedimentary formations; and that it was possibly coeval with the gigantic disturbances which folded up the gneiss into great contortions.

and to the Eastward.

Its elevation.

Date of granitic intrusion unknown.

* By Messrs. King and Foote.

Date of upheaval of ridge.

Subsequent to Ootatoor;

Of the elevation of the Thutchuncoorchy boss as far North as the confines of the Cretaceous rocks, we can, however, ascertain the date with great exactness, and prove that it occurred immediately subsequently to the formation of the Ootatoor group. During the formation of the newer groups, or at least of so much of them as now remain after extensive denudation, the Thutchuncoorchy tract formed a headland in the Cretaceous sea; and the conglomerates and sand banks, which abound in the lower beds of the Trichinopoly and Arrialoor groups, are formed in great part of its abraded constituents. In the lower beds, also, of the Cuddalore sandstones in the vicinity of Arrialoor, and many miles to the Northward, rounded pebbles of quartz and orthoclase felspar are tolerably abundant, and as no granite or any other rocks that could yield such materials occur anywhere in the surrounding country or for many miles to the Northward, there can be little doubt that these too were derived from the abrasion of the Thutchuncoorchy ridge.

prior to Trichinopoly Group.

Mineral character of granite.

The granite is for the most part a binary compound of quartz and felspar, sometimes compact and crystalline, but more frequently with the felspar (a pale yellow Orthoclase) in large crystals or cleavable masses, more or less penetrated with quartz. In some of the crystals the disposition of the quartz conforms to the cleavage planes of the felspar, forming the so-called graphic granite, but I have never observed any large masses of this peculiar rock. The relative proportions of the constituent minerals are also subject to much variation, and broad veins of almost pure quartz are by no means unfrequent. Mica occurs but rarely, but when present generally assumes the form of hexagonal plates not exceeding an inch or two in diameter*;

* The plates of mica upon which the native artists of Trichinopoly paint figures of birds, native costumes, local views, &c., are not derived from any local source, but are imported from Bengal, and are from the mica mines of Behar.

occasionally, however, it preponderates, and at Poruttagoody a band of pure black mica in small scales occurs, which appears to have crystallized out at the side of a vein of binary granite.*

Mixed with schistose rock.

The granite is much intermingled with gneiss and hornblendic-schist, which, in fact, preponderate even where the granite veins are largest and most numerous, as in the rock at Samiaveram. There is no massive intrusion of the granite, but the whole band may be considered rather as a mass of veins running generally in the planes of foliation of a shattered band of highly foliated hornblendic gneiss, which is frequently twisted and contorted in every direction and intimately interfoliated with the granite.†

At Samiaveram the granitic band is about 5 miles in breadth. Beyond this, in a Northerly direction, the veins are small and few in number, but they may be seen occasionally for about 4 miles further, after which no trace of granite is found.

Plains to north of granitic ridge.

The hills.

North of the granitic band the country falls away slightly, and its surface to within a short distance of the Southern flank of the hills, which, for about 30 miles Westward of the Madras road, bound the valley of the Cauvery, is covered with 'regur' of variable thickness. These hills, as is usually the case in hill groups of this part of India, rise abruptly from the plain, and when viewed from Trichinopoly or any other

* I have seen similar instances of bands of pure mica forming walls to the veins of binary granite in Cuttack : during the consolidation of the rock, (or crystallization from aqueous solution ?) the mica containing the magnesia and almost the whole of the iron in the original magma appears to have separated before the silica with the greater part of the potash, alumina, and lime began to crystallize out, as quartz and felspar.

† This is the usual character of the more granitic tracts of the country which I have visited. A granitic band of similar character extends for some distance along the north bank of the Puniar, in South Arcot, and I have subsequently met with rocks of the same character in the Sontal pergunnah of Kundit Kurayeh, in Bengal.

distant point, appear to form an almost continuous flat-topped range running in an East and West direction, and becoming gradually more elevated from East to West, when they terminate abruptly in an almost precipitous escarpment a few miles from Namcul Droog. On nearer approach they are seen to consist of two principal groups known respectively as the Collamullays and Puchamullays, and separated by a gap, contracted to a narrow pass at its Northern end, (through which a road leads to Ahtoor and Salem,) and opening out towards the South at Oopillapooram. In this gap rises the Tyaur, a large tributary of the Cauvery, which joins that river at the upper end of Seringham island. Of the two groups, that to the West, the Collamullays, attains a height of nearly 6,000 feet, while the elevation of the Puchamullays nowhere exceeds 3,000 feet, and is considerably less on the verge of their Eastern slope. In this direction they do not terminate abruptly as do the Collamullays on their Western flank, but a number of detached hills and short ranges, gradually diminishing in height, tail off to the Eastward, and terminate in Terany Hill, a small outlier of about 150 feet in height, at the foot of which rest, with almost undisturbed bedding, the oldest rocks of the sedimentary series.

Their elevation.

Detached hills to the Eastward.

Some miles to the North, in the neighbourhood of Volcondah and Perambaloor, are a few insolated bosses at some distance from the principal range. The Easternmost of these is Nedduvassel (Neddawassel) Hill, about 2 miles to the West of the Cretaceous rocks.

In the plain to the South of the hills are also a few detached bosses, but with the exception of Tullamullay, a magnificent solitary peak, which towers up to a height of more than 1,500 feet, almost opposite to the Western limit of the Collamullays, none attain sufficient elevation to become important features in the landscape.

To the South; Tullamullay.

The plain thus included between the hills and the Cauvery is about 16 or 18 miles in width, and, as described by Messrs. King and Foote, consists mainly of hornblendic gneiss, the East and West foliation of which coincides with the bedding of the original unmetamorphosed rocks, and with the axis of the great folds into which these rocks were bent up probably at a period coeval with their metamorphism. It also coincides, as we have seen, with the actual physical features of the country, the general direction of the Southern escarpment of the hill country, the granitic ridge of Thutchuncoorchy, and the bed of the Cauvery River.

Rocks of plain to South of hills.

Direction of foliation.

Coincident with the principal physical features.

Much of the gneiss to the South of the hills is hornblendic and highly foliated. This is well seen in the neighbourhood of Seraganoor, where we meet with the Western extremity of the Cretaceous rocks. The hornblende schist which occurs here is so highly foliated, that its weathered edges frequently present the appearance of fine shales, an appearance the more deceptive when, as is not unfrequently the case, the dip of the folia is at a comparatively low angle. This kind of rock appears to prevail along the Northern limits of the granitic band, and is met with at several places to the Eastward near the Southern boundary of the Cretaceous rocks. Its occurrence is principally of interest, inasmuch as no similar rock has been met with to the Northward, and as being evidently the source of many of the pebbles found in conglomerate beds of the Trichinopoly and Arrialoor formation.

Hornblende Schist. Seraganoor.

A few green-stone dykes are found in the neighbourhood of Ootatoor, evidently of prior date to the Cretaceous rocks, but are of no importance as a source of the material of the latter.

Dykes at Ootatoor.

I have mentioned that at the foot of the Terany Hill, the extreme

outlier to the South-east of the hill country of Northern Trichinopoly, lie the oldest rocks of the sedimentary series, the fossils of which (with some doubtful exceptions, plant remains,) afford somewhat ambiguous evidence of their age.

Terany Hill; plant-beds.

Some miles further to the North another small detached hill or ridge, that of Nedduvassel, rises almost at the border of the Cretaceous rocks; and beyond this point the narrow gneiss plain, 4 or 5 miles across, which intervenes between the hill country and the former rocks, widens out rapidly, and the hills trend away to the North-westward, and the Cretaceous rocks to the North-east, until, at Sadras, the whole extent of the Payen Ghât, where not covered by recent alluvia, consists of the old metamorphic rocks. Over a great part of this area the gneiss is very uniform in character. It is a hard, tough, compact rock, in which quartz and felspar predominate, but containing a variable proportion of hornblende, and frequently much garnet. It also contains, perhaps universally, a small amount of magnetic iron, although this can scarcely be detected in a hand specimen. This mineral is found as sand, accumulated in black streaks on the bed of every nullah in the country that drains Crystalline rocks, and not unfrequently in those from the sedimentary rocks, especially the coarse, half consolidated, sands of some portion of the Cretaceous series. In the Salem district, but especially in the Ahtoor gap, this mineral has been long known to occur in broad strings of the massive ore, and has been worked by the natives from time immemorial, for the manufacture of some of the best iron and steel produced in India or elsewhere. But this region is far distant from any of the now existing sedimentary rocks, and we must attribute the ferruginous element of certain beds of these latter to the local segregation of iron from some less concentrated source, such as the ordinary gneiss of the country would supply in its abraded material.

Gneiss of Northern Trichinopoly and S. Arcot.

Its mineral character.

Magnetic Iron in Gneiss.

Foliation of the Gneiss.

The foliation of the gneiss in the Northern part of the Trichinopoly district presents many contortions and irregularities, but its general tendency is to an E. N. E. and W. S. W. strike, the dip being sometimes to the North—sometimes to the South, of this prevalent axis.

Hills to the Westward.

Opposite Volcondah, which is situated on the water-shed of the Cauvery and Vellaur, the hill country extends to the North-west, gradually approaching the more Northerly groups of the mullays as far as Ahtoor. From this point both groups trend off to the Westward, enclosing between them a narrow pass through which flows the Vellaur, and which extends for 30 miles between the above and the adjoining groups of hills, opening out at Salem into the broad plain, 80 miles across, which is drained by the Cauvery and its tributaries, and extends up to the foot of the Nilghiris and the Western Ghâts.

Trap dykes of Volcondah.

In the neighbourhood of Volcondah and throughout the country to the North, greenstone dykes occur at distant intervals, some of them of considerable size, and running sometimes in the direction of the foliation, but more frequently at right angles to it.

Do not affect Cretaceous rocks.

No Trap pebbles in Cretaceous rocks.

Between Purawoy and Vapoor two of these dykes extend up to the boundary of the Cretaceous rocks, the Ootatoor, or lowest group of which, here rests on the gneiss. As in the case of the greenstone dykes near Ootatoor, the Cretaceous rocks are quite unaffected by these basaltic* intrusions, and although I have never found pebbles of the latter in the conglomerates of the Cretaceous rocks, their absence may be satisfactorily explained by the rarity of any local conglomerates in the beds immediately resting on the gneiss, the insignificance of the total mass of the trap as compared

* The rock is apparently Anamesite.

with that of the gneiss, and, lastly, the intense toughness of the rock itself and its slight tendency to break up into fragments of such size as could be easily transported by ordinary marine action.

Aspect of country.

The aspect of the low country of Trichinopoly on the gneiss, as on the Cretaceous rocks, is gently undulating and bare of vegetation, and except in the occasional occurrence of small bosses and low hills, such as I have described, the former differs but little from the latter. The vegetation depends more on the nature of the soil than on that of the underlying rock, and except a narrow strip at the foot of the hills, both the gneiss and the Cretaceous rocks are covered for the most part with black regur, which, from the water-shed of the Cauvery Northwards to the Vellaur, covers the country so thickly that but little of the underlying rock is anywhere exposed. In the drainage basin of the Cauvery the denudation has been greater, the average level of that river being much below that of the Vellaur, and the fall of the country which it drains on either side in consequence more rapid ; and it is in this part of the district that the most complicated and interesting features of its Geology are seen. To these I shall now return, commencing my description with that of the oldest of the stratified portion of the series, the plant beds near Ootatoor.

CHAPTER IV.—*Trichinopoly District—Plant Beds.*

Extent and position.

The small group of shales and sandstones which I have designated the Ootatoor Plant beds, are seen at several points cropping out in five (or six) separate patches from beneath the beds of the Ootatoor Group. Altogether they extend about 12 miles in a North and South direction, being finally overlapped by the beds of the Ootatoor Group at Cullpaudy on the North, and near Naicolum, a few miles South of Ootatoor, in the opposite direction. As a distinct group, they are of small extent and of little importance, but they become of much interest owing to the nature of their fossil contents, which, with a few doubtful exceptions presently to be noticed, consist of plant impressions, principally *Palæo-zamia*, all in a very fragmentary condition, and, owing to the softness of their shaley and sandy matrix, very readily obliterated by friction or carriage.

Age unsettled.

These remains have been pronounced by Mr. Oldham, who examined them on the spot, to be in part identical with the species which occur so abundantly in the intertrappean-beds of the Rajmahal hills in Bengal, the precise age of which is still very doubtful. Even as regards the plant-beds now noticed, (apart from any consideration of their contemporaneity with those of Rajmahal,) their position only proves that they are older than the Ootatoor Group, which is, probably, of middle-cretaceous age ; any thing beyond this must be determined by other evidence.

First noticed by Mr. Chas. Oldham. At Ootatoor.

These plant-beds were first noticed by Mr. Charles Oldham in the neighbourhood of Ootatoor, where the lowest beds are well seen in a little ravine about a mile to the East of the bungalow. At this spot they are seen cropping out from beneath the soft yellow gypseous clays of the Ootatoor Group, which, for some distance, form the left bank of the nullah, while a thick greenstone dyke, against the denuded face of which the latter were originally deposited, courses along the right bank. It is

at the extremity of this dyke, where two small branches of the nullah meet, that the plant-beds crop out; and in the broken ground drained by the upper branches of the nullah, the coarse sandstones, with intercalated bands of soft white and grey shale, of which they consist, are exceedingly well exposed.

Coarse conglomerate.

The bottom bed is a coarse, ferruginous sand, containing pebbles and large blocks of gneiss; the latter always much decomposed; one of these was not less than 6 feet long by 5 broad, and probably as much in height. Its height could only be guessed at, as it was half embedded in the matrix. It was rounded and quite decomposed, and it is probable that this decomposition of the minerals may have been complete previous to its being embedded in the sandy matrix. It is a noteworthy fact, that at this locality, and indeed generally where the plant-beds rest on the gneiss, the latter rock is decomposed to a considerable distance, and frequently to such an extent, that where the foliation is well marked, the decomposed gneiss has been mistaken both by myself and some of my colleagues for a bedded micaceous sandstone. Elsewhere, in the country immediately around, this decomposition of the gneiss is not usual, and it is also rarely seen where beds of the other groups rest upon that rock.

Gneiss decomposed.

Succeeding beds.

The conglomerates are succeeded by a series of fine micaceous shales, alternating with sandy shales and coarse semi-consolidated sands similar to that which forms the matrix of the boulder-bed.* These beds are exposed in

* The term "boulder-bed" used here, as well as on the map, is convenient as tending to distinguish these from ordinary and more widely spread conglomerates. But it must not be taken as implying that the blocks imbedded have been carried to any distance from their original locality. These coarse "boulder-beds" appear to be precisely what would result from the deposit of a tolerably fine sand, or silt, around and among the numerous and frequently very large blocks, which now strew the ground at the base of any of the isolated gneiss hills of the adjoining district. In all respects these rocks appear of a similar origin, and are, in fact, nothing but the deposits locally formed in this manner close to the old shores around which these plant-beds were originally accumulated. They are generally extremely local.

T. OLDHAM.

section in the banks of several little ravines, and dip generally at an angle of 5 or 6 degrees away from the gneiss, but without much regularity as regards direction. In the finer beds, especially the soft grey micaceous shales, the impressions of *Palæo-zamia* fronds are tolerably abundant; with the venation well exhibited in freshly broken specimens. The vegetable matter has entirely disappeared, and the softness of the shale is such that it is almost impossible to pack specimens for carriage without somewhat obliterating the more delicate parts of the impressions. Near the bottom is a band of ferruginous sand (similar to several which are intercalated in the shales) in which, together with some small pebbles of gneiss, I found several of an indurated clay, evidently derived from some earlier formed bed. I do not think, however, that this can be regarded as proving the former existence of a more ancient sedimentary formation. The fragments are small and few in number, and identical in appearance with some thin bands intercalated in the sands with which they occur. In thin shallow deposits where the level of the water, owing to local circumstances, is fluctuating, (and such may well have been the conditions under which the plant-beds were formed) nothing is more common than to see these deposits of mud, which have been laid bare to the sun and dried afterwards, broken up and embedded in a subsequent deposit. A similar instance has been noticed in the report on Talcheer.* This is the only case in which I have found fragments of sedimentary rocks in the plant-beds.

Plant remains.

Fragments of embedded clay.

At this spot the plant-beds are only exposed over a breadth of about 100 yards, and are then covered up by the Ootatoor clays: passing to the North they widen out, and the fine shales, of which they are principally composed, are seen around Oogalore, and also to the east of Terany, where they occupy a large area. Their mineral character varies but little. Grey and

Oogalore and Terany.

* Memoirs Geological Survey of India, Vol. I., page 52.

pale brown micaceous shales, with bands of grey and brown (ferruginous) sands everywhere form the bulk of the beds, and their prevailing grey tone contrasts strongly with the bright yellow ochreous tints of the Cretaceous rocks which succeed them. It would be tedious, as it is unnecessary, to enter into a detailed description of each separate locality, and I shall content myself with pointing out one or two of the more interesting occurrences, referring the reader to the map for the facts of the position and locality of such as offer no special peculiarity.

Junction of gneiss, Plant-beds, and Ootatoor Group.

On the opposite side of the regur-covered ridge to the East of Terany tank, a little ravine exposes the gneiss, plant-beds, and Ootatoor clays in noteworthy juxtaposition. A promontory of gneiss here advances more than a mile into the Cretaceous rocks, and terminates in the bank of the ravine, in a steep rocky angle which, possibly at one period, formed a little headland in the Cretaceous sea. Its partially denuded face slopes down at an angle of about 45°, and on it rest, with undisturbed bedding, the plant-beds and the Ootatoor clays; the former on the North, the latter on the South face. The plant-beds are the usual grey micaceous shales, and contain one or two large blocks of gneiss, but there is no regular bed of coarse conglomerate. These beds dip at a high angle, the lowest laminæ conforming to the inclined surface of the gneiss; but at the distance of a few yards the angle diminishes to not more than 8° or 10°. It would seem probable, the plant shales having been originally tranquilly deposited around the little headland, that, during the period of denudation that intervened previous to the deposition of the Ootatoor beds, all to the south of the gneiss promontory had been carried away, while those beds to the north had been preserved from destruction by the hard projecting mass of gneiss. Some of the lower beds of the Ootatoor Group close by are full of little angular fragments of the plant shale.

Between Kauray and Terany.

Between Kauray and Terany several good sections of the plant-beds are exposed in the little nullahs that supply Terany tank. Gneiss all around is much decomposed and the joints of the rock frequently filled with kunkur. The bottom bed of the plant-bearing group is variable, consisting sometimes of a red and white speckled sandstone, sometimes of a fine grey shale, and sometimes of a yellow ochreous shale, bearing some resemblance to the beds of the Ootatoor Group. The boulder-bed is here absent. To the east of the old Trichinopoly and Madras road a band of grey sandstone occurs near the bottom of the group, containing large boulder-like calcareous concretions of a flattened spheroidal form. They so much resemble some of the fossiliferous concretions of the Trichinopoly Group, that I examined them closely, in the hope of finding fossils, but at this point without success.

Concretion beds.

Crossing over the ridge that divides the catchment basins of Terany and Kauray tanks, this concretion bed is followed by a series of sandstones and fine compact pipe-clays, with mere traces of plant remains; and higher up come the usual micaceous shales abounding in the remains of Zamia, &c., and on re-descending from the ridge towards Kauray tank, a somewhat similar though by no means corresponding series of beds is crossed over in some of the small drainage nullahs at the eastern edge of Kauray tank, and almost at the bottom of the series some concretions similar to those above described are found jutting above the alluvial soil which has been washed down into the tank. Some of these I found to be full of small shells, both univalves and bivalves, but for the most part not recognizable. I at first thought that these were *probably* in situ, although not seen to be embedded, as they occurred just about the boundary of the plant-beds, and were very similar in appearance to the concretions above noticed, near the base of the formation north of Terany; but subsequent close examination of some specimens which I chipped off, disclosed *Cardium*

Fossils in concretions.

Hillanum, Astarte Planissima, and *Turritella Sowerbii,* an association which leaves little doubt of their Trichinopoly age, whether they be part of a little outlier, or have been brought to the spot by the natives.

Plant-beds at Varagapaudy.

A little to the north of Kauray the plant-beds are again overlapped by the Ootatoor Group, and do not re-appear till just beyond the village of Varagapaudy. A thick mass of soft brown sandy shale here occurs at the base of the group, and is well seen in the bed of the little stream to the North of the village. The shale is thoroughly reticulated with infiltrated kunkur, which, in the bed of the stream, stands out on the surface in masses like a tangled growth of Madrepore. This

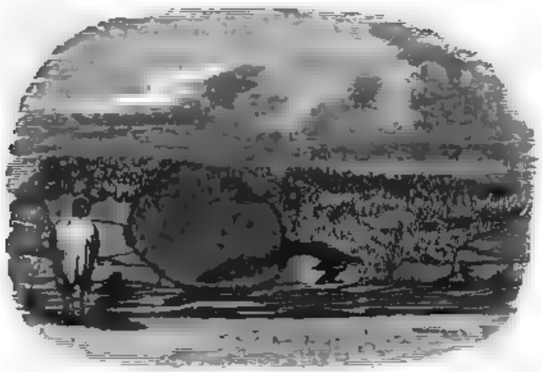
Kunkur.

only occurs close to the bottom of the beds, and is evidently of ulterior formation; it was probably deposited by waters infiltered from the overlying calcareous strata of the Ootatoor Group, which, being checked in their downward course by the less pervious gneiss, have thus saturated the lower beds of the plant shales, and deposited the calcareous matter in solution in the micaceous substance of the shales. A similar phenomenon is seen in another little nullah about a mile further to the north, where a bed of grey micaceous shale is seen resting on the gneiss, and in this latter case the deposit has taken place in the joint-like fissures, (probably due to shrinking) by which the mass is divided. They present a curious appearance, where, in the bed of the nullah, the soft shale has been eroded, leaving a system of intersecting partitions standing out like boxes on the surface. Many acres of the surface of the ground to the west of Coodicaud is thickly covered with kunkur, probably from denuded beds of the plant-bearing group; judging from the sections seen in the banks of the nullahs, the deposit must average not less than four or five feet in thickness.

The ground to the north of Coodicaud is much broken up by gullies, and good sections of the plant-beds, consisting of alternations of micaceous shales and grey sandstones and grits, with great calcareous concretions, are everywhere exposed. One of these concretions, about six feet in diameter, is represented in the accompanying sketch (Fig. 2).

Plant-beds North of Coodicaud.

FIG. 2. CONCRETION IN PLANT-BEDS, NEAR COODICAUD.



The beds dip to the East and North-east, generally at a low angle, but sometimes as much as 15° to 20°. The plant remains here are not well preserved: I was myself unsuccessful in meeting with any, but Mr. Oldham was more fortunate.

Dip of bedding.

Plant remains.

West of Coodicaud a few gneiss blocks are found in the lower beds of shale, and at one point a regular boulder-bed, consisting of little else than a heap of blocks of decomposed gneiss, is exposed in a small gully. Crowning the high regur-covered ridge to the North-west, the boulder-bed is again met with, its out-crop being not less than a quarter of a mile in width, and extending up to the edge of the overlying coral limestone. As usual it consists wholly of decomposed boulders, the interstices of which are filled with a fine gneissose silt, similar to that of which the shales of the plant-beds are chiefly composed.

Boulder-bed.

It extends as far Northwards as Cullpaudy, and is then finally overlapped by the limestones of the Ootatoor Group. Beyond Cullpaudy I have myself seen no traces of plants in these beds, but in some beds to the North-east of Maravattoor, which strongly resemble the plant-beds in mineral character, Mr. Oldham informed me that he found recognizable specimens of the plants which characterize the beds of Ootatoor and Terany. On hearing from Dr. Oldham to this effect, I revisited them with a view to ascertain their stratigraphical relations. With this object I examined all the exposed sections, from where they are seen to rest on the gneiss, up to beds of undoubted Ootatoor age, but without detecting any unconformity or any sudden change of mineral character such as might lead me to suspect the existence of distinct formations, while shales lithologically similar to the above are seen close by intercalated with beds indubitably of Ootatoor age. I did not find any remains of plants. Under these circumstances I cannot at present regard the Maravattoor beds as of the true plant-bearing group, and will treat them provisionally at least as a part of the Ootatoor formation.*

Plant-beds of Maravattoor apparently of Ootatoor age.

To return to the country south of Ootatoor. Near Naicolum the boulder-bed occurs at the base of the plant-beds, presenting the same typical peculiarities as characterize it near Cullpaudy. The plant-beds are not very extensively exposed, but abound in Zamias and the usual sedge-like stems and leaves, and dip beneath a narrow mass of coral-reef limestone that extends from the Southern corner of the large Ootatoor tank.

Plant-beds at Naicolum.

The above are the only localities at which beds, undoubtedly belonging to the plant-bearing group, are exposed. A bed of boulders identical with that of Naicolum and Cullpaudy does indeed occur at several places at the base of the Ootatoor Group, and I have but little doubt that it

Boulder-bed at base of Ootatoor Group probably coeval with plant-beds.

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* See note at end of this chapter.

is a remnant of the plant-bearing formation, the softer shales and friable sands having been denuded. The most notable instance of this occurs at Cullygoody, on the South-east boundary of the Trichinopoly formation, where an extensive boulder-bed, followed by a mass of fine micaceous shales and grey sands, with intercalated bands of calcareous grit, *underlies* the coral-reef limestone. These shales and sands bear so much resemblance to certain beds of the plant-bearing group, that although I was unsuccessful in discovering plant remains in them, I should have referred them to that group, did they not contain marine fossils, which renders it at least improbable that the beds are of contemporaneous formation. The fossils of these beds are indeed, so far as they are determinable, peculiar to this Cullygoody deposit, at least I have not met with any of them in beds of the Ootatoor or Trichinopoly Group, but a fragment of a *belemnite*, which bears some resemblance to an Ootatoor species, interpreted by the fact that the genus only occurs elsewhere in this district in beds of undoubted Ootatoor age, induces me to believe that the Cullygoody beds are a peculiar local deposit of that group.

At Cullygoody.

Beds with marine fossils.

The age of these plant-beds is a subject upon which I do not feel qualified to pronounce any decided opinion. The only fact to be gathered from their stratigraphical position in Trichinopoly is, that they are older than the Ootatoor Group, or in other words, that they are not newer than the lower divisions of the Cretaceous period; the Ootatoor beds being, as is indicated by their cephalopoda, probably of Middle-cretaceous age. Apart from considerations founded on their contemporaneity with the Zamia beds of Cutch, I see no physical reason to believe that they are *very much* older than the Cretaceous formation. They have been indeed extensively denuded, but I have met with no such unequivocal evidence of their disturbance, as their prevalent dip of 6 to 15 degrees is not higher than

Age of plant-beds.

that of the Ootatoor Group, which, as I shall show further on, there is every reason to believe is one of original deposition.

Dr. Oldham's opinion.

Mr. Oldham who, as I have mentioned, examined the plants of these beds on the spot, has recorded his opinion to the effect that the beds are of the same general Geological epoch as those of Rajmahal and Cutch, and that they probably represent some portion of the older Mesozoic groups of European Geologists :* the Cutch plant-beds are, as pointed out by Mr. Oldham, stated by Captain Grant to underlie the beds with Oolitic marine fossils ; and hence the inference that the Rajmahal beds (and consequently the Ootatoor plant-beds also) are not more recent than the lower Oolitic. The contemporaneity of these various deposits and their inferior Oolitic age is thus deduced partly from the affinities of their fossil floras, partly, as we have seen, from the information regarding the stratigraphical relation of the Cutch deposit afforded by Captain Grant.

Under these circumstances I think it not superfluous to mention some circumstances, weak as I acknowledge them to be, in evidence upon this point, which, in the absence of Dr. Oldham's conclusions to the contrary, would have impressed me with the idea that the plant-beds near Ootatoor and elsewhere in this district are not much older than the beds which overlie them.

Reasons for inferring a later date
Undisturbed stratification.

I have already mentioned that the apparently undisturbed condition of the plant-bearing formation would lead me to infer, the probability at least, that the formation in question is of no great antiquity, also that at Maravattoor shales, in which Dr. Oldham detected plant remains which he identified with those of the Ootatoor plant-beds, occur apparently at the base of the Ootatoor Group. I am not inclined to lay any great stress upon this fact, but still, inasmuch as on careful and indeed repeated examination of the sections, I saw no reason to believe that these

* Memoirs Geological Survey of India, Vol. II,. page 324.

beds formed a distinct formation, the inference must stand for what it is worth, until re-examination may prove it to be erroneous. Again some specimens of wood from the *Ootatoor formation*, which* I submitted to Dr. Thomson, were pronounced by him to be Cycadaceous, so far as he could judge from inspection and without examining microscopic sections: and, thirdly, my colleague, Mr. Foote, detected what appeared to be a portion of a Zamia frond in the bottom beds of the Trichinopoly Group near Alundanapuram.

Cycadaceous wood of Ootatoor Group.

With these remarks I may now leave the matter to be decided by future evidence. The facts I have brought forward are not, I admit, at all conclusive inthemselves as bearing on the question at issue, but still they offer at least one difficulty to be removed, before we can admit the lower Oolitic age, assigned to the beds by Dr. Oldham, to be an accepted truth.

Objections by no means conclusive.

Note by Mr. Oldham.—In the summer of 1859, at which time considerable progress had been made in mapping the districts now reported on, I visited Trichinopoly, and went over the greater portion of these Cretaceous rocks in some detail. Among other points in which I was much interested, I examined all those localities along the western boundary of the Cretaceous rocks, where the plant-bearing beds had been noticed from Ootatoor Northwards. In all cases I found these, as described by Mr. Blanford, similar in their lithological character, and having the same relation of marked unconformity with the beds above, these beds being then supposed to be of Neocomian age. Passing Northwards to Maravattoor, I found there beds of the same mineral aspect, and in these beds remains of the same plants as were seen elsewhere. These beds had not

* Cycadaceous wood, to the supposed occurrence of which in the Ootatoor beds Mr. Blanford refers, has been found even in the older alluvium of this country. And even assuming the occurrence of the supposed Zamia frond from Alundanapuram confirmed, it by no means follows that it was a Zamia of the same species a those collected from the plant beds.—T. OLDHAM.

been noticed on the map, and having simply determined the existence of these plant remains, without delaying to investigate more carefully their relations, I communicated the facts to Mr. Blanford, leaving it to him to work out the relations of these beds, when he came to finish this portion of the map.

The results arrived at during my personal examination of these plant-bearing beds, I briefly stated in a short notice in the 2nd volume of these Memoirs (page 320). In this paper I took as the true age of the Ootatoor beds what was then supposed to be so, and assumed them to be Neocomian. Since then Mr. Blanford has had fuller opportunities of working out the fossils of these beds, and so far as the Cephalopoda are concerned (the only group as yet examined in any detail), they seem to indicate that the Ootatoor beds are not older than the middle portion of the Cretaceous period. So far, of course, the reasoning as to the age of these plant-beds must be modified, and, as very justly stated by Mr. Blanford, all that is proved by their position in Trichinopoly is that they are not newer than the lower portion of the Middle Cretaceous period.

Mr. Blanford, however, as will have been seen, considered that these beds at Maravattoor were conformably in sequence with beds containing marine fossils of undoubted Ootatoor age, and were probably intercalated with them, while the fact of his having found no trace of the remains of plants during his careful and repeated examination of the beds, left a doubt hanging over their true relations, which it was all important to solve if possible. As soon, therefore, as I was aware of these results arrived at by Mr. Blanford, I made arrangements to revisit the ground, and to determine if any thing further could be made out. This I have just accomplished and with the following result:—

1. The plants first noticed by myself and Mr. Charles Æ. Oldham in 1859, do occur in several beds; these plants are identical with several found in the Rajmahal beds, and there are two which appear to be identical with the only two recognizable species figured as occurring in Cutch.

They occur in beds of the same general lithological character as in other localities, in the Trichinopoly district, where similar plants have been found.

The gneiss, at the junction with these beds and for some distance from the junction, is in the same general condition, as where seen under the other plant-beds, and has been subject to the same forces (*see* page 40).

The beds in which the plants occur have gravels and conglomerates associated with them as in other places.

Immediately over these beds with plants occur others, which in general aspect, in color, and in composition, resemble those holding plants. But they differ in structure; the plant-beds are clunchy irregular sands and clays, with a few shaly irregular layers and coarse conglomerates, some of the blocks 6 to 8 feet across. The beds above are in comparatively regular and thin layers continuously super-imposed, and without conglomerates. There does not appear to be any passage or transition in these respects. There *is* apparently conformity in dip.

The plants occur close to the gneiss, and also at intervals up to the latter beds, but in these no plants were traceable; and with the lowest of these latter are intercalated concretionary calcareous masses with marine shells. The area of the plant-bearing beds is very small, and is confined to the bottom of a little valley or depression in the general surface of the country, in which they are exposed in a small water-course, the upper beds lapping over them on either side up to junction with gneiss.

The case appears to be one of apparent conformity and sequence, due to the fact that the lower beds were largely denuded, and furnished the materials from which the upper were formed, but there was found no good evidence of intercalation. This is of course only negative evidence, but taking into consideration the facts very clearly seen elsewhere (at five out of the six different localities where these plants have been found) of marked unconformity and great denudation, I think there can be little hesitation in admitting the plant-beds at Maravattoor as identical with

the plant-beds' at Ootatoor and elsewhere, and as being quite distinct from the Ootatoor beds which cap them, notwithstanding any local appearance of conformity.

The actual geological age of these plant-beds cannot be decided from this district alone, and there is no use in entering upon the question here.

I should mention that in one or two of the layers close to the gneiss, there occur sparsely disseminated a few casts of a small bivalve, like a Cyclas, but they are poorly preserved, and being solely casts, are not recognizable.

T. OLDHAM.

November 1861.

CHAPTER V.—*Ootatoor Group.—(a) Coral Reef Limestone.*

Occurs at base of Ootatoor Group.

THE peculiar formation which I have thus designated occurs in isolated ridges and bosses at several points along the boundary of the Cretaceous rocks, the lowest beds of which are heaped around it, and occasionally in a great measure formed of its debris. It rests sometimes on the plant-beds, and sometimes, and more frequently, on the gneiss, or on the lowest beds of the Ootatoor Group, and appears to belong exclusively to the earliest portion of the Ootatoor period, during which the clays and argillaceous limestone of the Ootatoor Group, abounding in the varied forms of Cretaceous cephalopoda, indicate the existence of a moderately deep sea. In one case indeed, that alluded to in the preceding pages of the limestone at Cullygoody, there is no proof to be derived from stratigraphical evidence, that the rock in question is not of posterior date to the formation of the Ootatoor Group; inasmuch as, while these beds are locally absent, (or such of them as exist underlie the limestone,) those of the Trichinopoly Group rest immediately upon it. This evidence

however, in favor of the latter view is merely negative, and is, I think, overborne by other considerations which will appear in the course of description. To this I now proceed, commencing with the limestone at the Western extremity of the Cretaceous rocks.

At Tripatoor.

About a mile to the South of Tripatoor, and to the East of the shallow nullah that flows down from that village, a broad rocky ridge, rising several feet above the level of the surrounding land, marks the boundary of the Cretaceous rocks. The rock, of which this ridge is composed, differs strikingly both in structure and external appearance, from the ordinary sedimentary rocks of the district: it is a compact splintery limestone of a pale pink,

Character of limestone.

or a cream color, sonorous and brittle under the hammer, and breaking with a more or less conchoidal fracture with equal facility in any direction. In general it exhibits no distinct bedding, but occasionally a thick slab-like structure is perceptible over a limited area. Small irregular cavities sometimes occur in it, which are partially or wholly filled with crystallized calc-spar. Ex-

Weathered surfaces.

ternally the rock is much eroded, and often deeply honeycombed by the action of the atmosphere; it is sometimes pale, sometimes black on the surface, and rarely exhibits to the naked eye any trace of organic structure. In some places it con-

Fossil contents.

tains a few small bivalves and corals, and occasionally a coarsely-ribbed pecten of a species peculiar to this rock. In other parts, and especially towards the base, it exhibits a mass of irregular white streaks from a few lines to two or three inches in thickness, preserving an irregular parallelism to each other, and never intersecting. No organic structure is perceptible in these streaks to the naked eye, and the rock shows no tendency to break

Corals.

along them in preference to any other direction, but an occasional weathered surface shows that they are corals of various species of *Astræa,* seen in section, evidently

in situ, and embedded with the rock on which they successively grew. The accompanying wood-cut (Fig. 3) will serve to convey some idea of the appearance presented by this coral limestone. The mass represented is a small isolated boss which occurs at Muddam, a few miles to the East of Tripatoor

FIG. 3. BOSS OF CORAL-REEF LIMESTONE NEAR MUDDAM, TRIPATOOR.

Form and extent of ridge.

The total length of the Tripatoor ridge is about half a mile. It is divided in the middle by a small nullah, and in the interval are deposited some soft grey shales much resembling those of the plant-beds, but which appear to belong to the Ootatoor Group. On the western half of the ridge they lap round the base, and are seen in a small field drain, resting against the highly inclined face of the rock at angles of 20° to 30°, with one or two lenticular calcareous bands at their base, enclosing a few pebbles of the limestone. About fifty yards from the limestone they are covered up by the coarse conglomerate that occurs at the base of the Trichinopoly Group, and this latter also is full of pebbles and boulders of the limestone. In the interval, between the two main divisions of the ridge, a small isolated boss of the limestone, which has probably been separated from the main ridge by denudation,

Beds around it.

is exposed in a little gully which cuts through the Ootatoor shales, and the latter are clearly seen dipping away in all directions from the boss. Passing to the North-east along the boundary of the Ootatoor Group, we meet with a few masses of limestone similar to that above described on the old Madras road, about half way between Agaram and Naicolum, close to an old ruined temple. So far as can be made out, these appear to be surrounded by the Ootatoor clays, which occur quite at the base of the group, and are exposed in the gullies close by. Their relations are not, however, very clearly seen, as the limestone only is visible, except in one instance, projecting above the soil.

Naicolum ridge.

Again, about a mile to the East of Naicolum, a series of limestone rocks, showing the usual characters of the coral limestone, and frequently exhibiting the white streaks of embedded corals, extends in a line for about a quarter of a mile from the southern extremity of the large tank (*see* map). At this spot, to which I have already referred when speaking of the plant-beds, the limestone ridge (for though not visibly continuous above the soil, it may be considered as such,) rests upon the Zamia shales which dip towards it at a low angle, while on its South-eastern flank the Ootatoor shales are seen in the broken ground dipping away to the South-east at an angle of not more than 3 or 4 degrees. There is no conglomerate at their base, the lowest beds being fine ochreous shales, with ferruginous concretions, but there can be no doubt, judging from their position and dip, that they rest upon the limestone. A conglomerate bed is indeed an exceptional occurrence at the base of the Ootatoor Group, whatever be the nature of the rock upon which it rests.

East of Naicolum.

Its position.

In the Naicolum limestone I found, in addition to the corals, such as occur in the Tripatoor ridge, a *Terebratula* and fragments of *Pentacrinite* stems ; also *Belemnites*, and, what is very rare in the coral-reef limestone, quartz

Fossils of limestone.

pebbles about an inch in diameter, and a fragment of stone probably derived from some earlier formed portion of the formation, and re-embedded. Here also I noticed that some of the white veins, which had been laid bare by weathering, exhibited eroded but still distinct calices of the coral composing them.

Pebbles in limestone.

It is worthy of remark, that while fragments of Pentacrinite stems occur in several cases embedded in the coral-reef limestone, nowhere else throughout the Cretaceous series (excepting in one instance at the base of the Arrialoor Group) have I met with a vestige of these fossils; or indeed with any species of the order Crinoidea, with the exception of some Marsupites in the Arrialoor Group.

Pentacrinites.

Again, about a mile to the North-east of Kauray, we meet with a prominent ridge of limestone, part of which presents the characters of the coral-reef limestone, and part evidently belongs to the Ootatoor Group. The ridge which rises some 20 or 30 feet above the average level of the soft shales around it, runs at right angles to the general strike of the Ootatoor beds; the limestone beds of the latter having been deposited around a ridge similar to that of Tripatoor, and concealing a great part of its surface. The coral-reef limestone is thus only exposed at its Western extremity, where the Ootatoor beds have been removed by denudation, and where it rests apparently on some calcareous shales, the relations of which are by no means clear.

Kauray ridge.

Ootatoor.

It is full of corals, principally of various forms of *Astræadæ*, among which a *Dimorphastræa* is very common, and which stand out prominently on the weathered surface of the limestone, their lamellæ, sharp and distinct, reminding one of the silicified corals of the English Mountain limestone.

Corals abundant.

The overlying limestone beds of the Ootatoor Group, the mineral characters of which are quite local, and due evidently to their material being derived principally

Overlying beds.

from the old coral reef, are also full of corals, and except that they are distinctly bedded, and dip concordantly with the overlying shales, are scarcely to be distinguished from the massive limestone on which they rest.

Varagapaudy ridge.

A precisely similar case occurs about a mile further to the North-east, near the village of Varagapaudy. Here also the coral limestone, which contains corals similar to those of the Kauray limestone, and in similar condition, is exposed only towards the western extremity of the ridge, where it extends beyond the boundary of the Ootatoor beds, and is seen resting on the gneiss. To the East it is concealed beneath the limestones at the base of the Ootatoor Group, which are also seen dipping in all directions from the sides of the ridge, containing corals, which resemble, and are probably identical with, those in the reef limestone.

Sirgumpore ridge.

Again near Sirgumpore, on the North bank of that branch of the Murdayaur that flows past the village, there is a range of little bosses of coral-reef limestone. They are very small, the largest being only 30 feet across, and appear to rest on a mass of gypseous shales, which in mineral character are undistinguishable from the local shales of the Ootatoor Group, while they are certainly unconformable on the plant-beds close by.

Position on the beds of Ootatoor Group.

I could not obtain any evidence to substantiate their infra-position, but so far as the dip of the shales could be relied on, they appeared to underlie the limestone. Moreover, on the opposite side of the limestone, (and where the limestone was absent, on the shales,) rested a bed of conglomeratic limestone, full of Ootatoor fossils, and containing fragments of the coral limestone, whereas neither fossils nor pebbles occur in the shales below. This bed of limestone, which is very conspicuous, may be traced across the nullah striking to the South-east, and the shales beneath it, somewhat changed in mineral character, are also well exposed to the South of the nullah, where they undoubtedly overlie the Varagapaudy ridge. It would seem therefore as if the coral-reef limestone were

partly of subsequent formation to the lowest beds of the Ootatoor Group, in which, as we shall presently see, small local unconformities, indicating irregular deposition, are of very frequent occurrence.

Cullpaudy ridge.

Immediately South of Cullpaudy I have mapped a considerable area as coral-reef limestone. Except, however, close to the village very little of it is seen: the ground, which is high, being for the most thickly covered with regur, through which the limestone peeps up here and there. Some blocks of it that had been dug up by quarrymen, and were freshly broken, much resembled the limestones of the Ootatoor Group which rest upon it. They contained a considerable amount of ferruginous clay, as does also much of the Tripatoor limestone, but in the freshly broken masses the iron was not peroxidised, but, as is generally the case in unweathered limestones, existed as a carbonate, giving a bluish-grey color to the stone. The stone contained, moreover, many irregular veins and "vugs" of crystallized calc-spar, the filling of pre-existing cavities. This character I have never noticed in the bedded limestones of the overlying deposits. Some fragments exhibit, when broken, a loose arenaceous structure, the particles of calcareous sand of which they are composed being merely agglutinated and not cemented, as is usually the case, into a dense limestone.

Limestone not pure.

Loose structure.

Limestone at Maravattoor.

Several little patches of coral-reef limestone occur in the neighbourhood of Maravattoor, abounding in corals, some of them of very large size. These bosses are, however, of so small an extent that they could not be shown on the map without much exaggeration. The limestone is of a sandy structure, similar to that at Cullpaudy.

North of Maravattoor.

Beyond Maravattoor no coral-reef limestone is met with *in situ*, for about 8 miles, but in the conglomerates at the base of the Ootatoor Group, which are well exposed in the nullah East of Parully, numerous fragments of the limestone and

corals, similar to those at Maravattoor, testify to the former existence of a reef somewhere in the vicinity.

Poothoor and Purawoy.

Between Poothoor and Purawoy I met with two instances of the coral-reef limestone, in the one case (that nearest to Poothoor,) resting on gneiss, and exhibiting the characteristic streaks of the now embedded and once encrusting corals. This patch is about 25 yards across, and not more than a few feet in thickness. The other patch occurs at the Southern end of the bund of a small tank, half a mile South of Purawoy, and is still smaller in extent. Close by some blocks of conglomerate in the Ootatoor beds contain large sub-angular fragments of the limestone, some of them upwards of a foot in diameter, and containing the characteristic coral streaks. They are sandy in structure, similar to the limestone at Maravattoor. Several small masses of a similar arenaceous limestone occur to the North of Olapaudy, at the foot of the limestone ridge formed by the lower beds of the Ootatoor Group, but no one of them is more than a few feet in diameter, and they do not contain any corals.

Bosses at Olapaudy.

All the coral-reef limestone ridges hitherto described, occur unquestionably at the base of the Ootatoor Group, either resting on gneiss, or on the plant-beds, or, possibly in one or two cases, on some of the first-formed deposits of the Ootatoor Group. We have now to consider some other cases in which the age of the limestone, so far as can be judged from mere stratigraphic evidence, is open to some doubt, but which, as there is no positive evidence to prove a different epoch of formation, and which, as in all essential characters the limestones resemble those above described, I therefore consider in this place.

Instances of doubtful age.

Boss at Muddam.

The first of which I have to speak, is one to which I have already briefly alluded, and which is illustrated in the wood-cut (page 54). It will be seen on reference to the map, that along the Southern boundary of the strip of

Cretaceous rocks that extends across the Madras road at Seraganoor, a series of little outliers of the Trichinopoly Grouprest on the disturbed beds of the Ootatoor Group, which, at Seraganoor and one or two other places are seen to be faulted against the gneiss. In the midst of one of these little outliers, close to the spot marked on the map as the site of the (now extinct) village of Muddam, a little boss of the coralliferous foim of the limestone appears *in situ*, as shown in the figure. Its exact relations to the Cretaceous rocks are not ascertainable, and I believed at first, judging from the faulting of the Ootatoor beds close by, that it furnished an indubitable instance of coral-reef limestone of Trichinopoly age. Although the boss itself is quite insignificant in size (only a couple of yards or so in diameter), it was of great importance to ascertain the truth of this inference on account of the bearing that the fact, if established, would have on any inference as to the age of the larger and more important ridges of similar limestone at Cullygoody, for if coral-reef limestone, undistinguishable from that which we have shown to occur frequently at the base of the Ootatoor Group, could be shown to have been also formed at the commencement of the Trichinopoly epoch, the negative reasons which lead us to assign a pre-Ootatoor age to the Cullygoody limestone, would entirely fall to the ground; and thus, as I have shown a few pages back, the age both of the limestone and of the fossiliferous boulders at that locality would become involved in greater doubt than ever. On this account, therefore, I searched carefully for any evidence that could aid in deciding the age of the little Muddam boss, and the result, founded on the following grounds, is that there is no reason to believe this case exceptional in point of age.

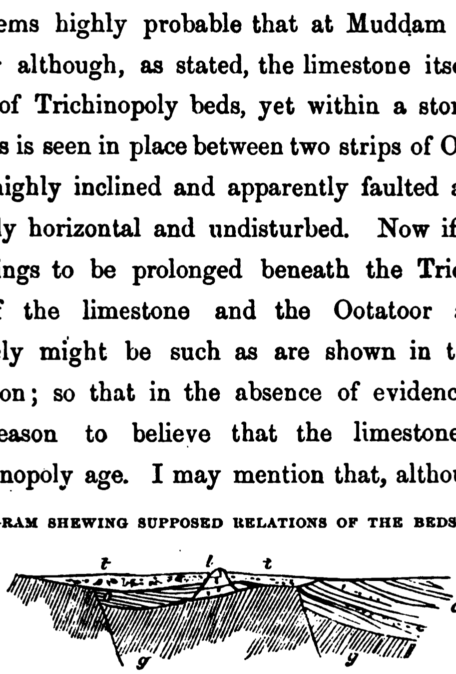
Its age discussed.

The Ootatoor beds are, as I have stated, unmistakeably faulted against the gneiss at Seraganoor; and at one or two other places on this boundary, between that village and Paroovalapoor, there is good reason to infer a similar disturbance, but

Reasons for its Ootatoor age.

at other places, which I shall describe more at length in a subsequent chapter, it is equally certain that the lower beds rest undisturbed on the crystalline rocks; so that this line of boundary is formed by a series of small parallel faults between which the bottom beds of the Ootatoor group are occasionally exposed, where not concealed by Trichinopoly outliers. It seems highly probable that at Muddam this latter condition obtains, for although, as stated, the limestone itself protrudes from a little outlier of Trichinopoly beds, yet within a stone's throw to the West of it gneiss is seen in place between two strips of Ootatoor beds, that to the North highly inclined and apparently faulted against it, that to the South nearly horizontal and undisturbed. Now if we suppose this condition of things to be prolonged beneath the Trichinopoly outlier, the relation of the limestone and the Ootatoor and Trichinopoly beds respectively might be such as are shown in the accompanying imaginary section; so that in the absence of evidence to the contrary, there is no reason to believe that the limestone in this case is really of Trichinopoly age. I may mention that, although elsewhere the

FIG. 4. DIAGRAM SHEWING SUPPOSED RELATIONS OF THE BEDS NEAR MUDDAM.



o. Ootatoor beds. *t*. Trichinopoly beds. *g*. Gneiss, &c. *l*. Coralline limestone.

Ootatoor and Trichinopoly beds are frequently undistinguishable in mineral character, in this immediate neighbourhood there is no danger of confounding them; the one being fine gypseous shales, the other a coarse gneissose conglomerate, frequently full of the debris of the denuded lower beds.

Cullygoody ridges.

We now pass on to the limestone at Cullygoody, which is in all respects the finest example met with of this peculiar rock. It forms a broken ridge or series of ridges about 3½ miles long, extending along the edge of the Cretaceous rocks from

near Palumbaddy to a point about a mile and a half north of Cullygoody.

Their extent.

Beyond this a few scattered patches occur of less importance, only two of them being of such size as can be shown on the map; but, with one exception, in all probability originally connected with the main ridge, which must thus have extended to a length of not less than 6 miles. The exceptional case, a patch between the villages of Aumarasure and Malarasure is interesting, as it occurs on the gneiss at the distance of nearly a mile from any of the older Cretaceous rocks, and affords the only instance of the kind I have met with.

North of Cullygoody.

Of the main ridge, that part immediately to the North of Cullygoody, shown in the accompanying figure (Fig. 5), is most clearly exposed, and that in which the peculiar characteristics of this singular formation are best to be studied. Its greatest width is about 250 yards, as roughly estimated by pacing. It rises with a gentle slope from the gneiss, presenting a rugged surface of

FIG. 5. LIMESTONE RIDGES NEAR CULLYGOODY.

close-packed limestone masses. Towards its base no definite structure is perceptible, the great protruding hummocks being pitted and honey-combed into a variety of irregular forms by the action of the weather, but in the middle and upper parts a very distinct bedded structure is manifested in the arrangement of the masses, although there is no corresponding change in the mineral character of the rock.

Bedded structure of upper part.

At the summit of the slope the rock disappears beneath regur, and a short distance beyond this the Trichinopoly beds, resting on the limestone, are seen wherever broken ground exposes the underlying rocks. The rock, of which the greater part of the ridge is composed, bears a close resemblance to that of Tripatoor. The streaked coralliferous variety is occasionally seen towards the base, and elsewhere the rock is either white, or of a pale flesh or yellow color. The first of these three varieties presents rather an earthy or chalky fracture, and, so far as can be judged by the eye, unaided by chemical tests, would seem to be an almost pure indurated calcareous mud. This, however, is never seen in large masses, but only in the interior of blocks of the flesh colored variety, which is hard and sub-crystalline, being, in fact, the white rock altered by the infiltration of a calcareous solution. The third-mentioned variety is the most common, and this derives its color from the admixture of an ochreous clay, similar to that which occurs so largely in the bedded deposits of the Ootatoor Group. In this variety, which occurs both at the base and in the higher parts of the ridge, fossils are occasionally found, and sometimes a great part of the stone consists of comminuted shells. Close to the bottom a few pebbles of gneiss, apparently derived from the underlying boulder-bed, are occasionally met with, but I have never obtained these at more than a foot or two from the bottom, and throughout the upper part of the ridge I have never met with a single

Mineral characters.

Chalky variety.

Flesh colored crystalline.

Ochreous argillaceous.

Comminuted shells.

Pebbles in limestone.

pebble of any kind. The fossils I have noticed are not very numerous, but are of interest, as tending to confirm the view of the Ootatoor age of the limestone; they consist of:—

Fossils.

Corals.—1 Species.

Rhynchonella.—1 Species.

Ostrea.—1 Species, elongated and plicated like *O. larva,* much resembling a species common in the Ootatoor Group.

Pecten.—1 Species: the large-ribbed species noticed at Tripatoor.

Belemnites.—1 Species, not determinable.

Bedded structure not due to regular stratification.

I have already spoken of the bedded structure which is so distinct in the Cullygoody ridge, and which may be noticed also in the ridge South of Vadoogapaitty, although less strongly marked. At Cullygoody, as may be seen in the figure (Fig. 5), it is so marked and regular, (the strike being coincident with that of the ridge and the dip away from the gneiss,) that the limestone might be easily mistaken for a regularly stratified deposit. That it is not so, there is, however, sufficient evidence, even had we not the analogy of the limestone elsewhere to induce scepticism on this head. In the first place, whenever the lower part of the limestone is seen, whether at the ends or side of the ridge, or in the breaks which occur in it at one or two points, there is no trace of bedded structure, and the limestone is seen to rest on an uneven, but, on the whole, nearly horizontal bottom. The bedded structure occurs exclusively in the middle and upper part of the ridge, only in the latter, where the ridge is low, the beds or slabs are from 2 to 4 feet thick, and the amount of their dip (frequently 12 to 15 degrees, occasionally as much as 30) is perfectly incompatible with the horizontality of the base, to the very irregular outline of which the strike in no way conforms. Again the homogeneity of the rock, of little value as positive evidence,

at least does not support the view which would refer the structure to original stratification, and is equally compatible with that which would attribute it to a shrinking in the interior of the mass, an explanation suggested by Mr. Jukes to account for a somewhat similar phenomenon in a coral-reef sandstone at Heron Island.* To this point I shall return presently, when we come to consider the nature and origin of the limestone formation regarded as a whole, and in the meantime I will briefly recount some other noteworthy features of the Cullygoody ridge, and recapitulate the evidence which induces me to regard this as coeval with the limestone of Tripatoor.

Due to shrinking ?

At the Northern extremity of the principal ridge the mutual relations of the Trichinopoly beds, the coral-reef limestone, and the boulder-bed and fossiliferous grits previously adverted to (page 47), are beautifully exhibited in a little nullah. A view of the locality is given in the annexed sketch (Fig. 6).

Stratigraphical relation of limestone near Cullygoody.

FIG. 6. BOULDER-BED, CORAL-REEF LIMESTONE AND TRICHINOPOLY BEDS. NORTH OF CULLYGOODY.

* See Voyage of the *Fly*, Vol. I., page 8, 9.

The spectator is supposed to be looking Eastward. The rising ground on which the light falls in the mid distance is capped with coral limestone, the bare rocky masses of which are also seen stretching along the ridge to the Southward. At its base the dark bank of the little nullah is formed by the boulder-bed, of which 8 or 10 feet are exposed, and although so close to the limestone, containing not a single fragment of any other rock than gneiss. In front of the ridge, and also intersected by the nullah, are seen the flaggy limestones and shales at the base of the Trichinopoly group, resting at an angle of about 30° on the denuded face of the boulder-bed in the nullah section, and on that of the coral limestone a few yards further South. This high dip is, however, quite local, and at the distance of a few yards it diminishes to not more than 5° or 6°. Almost at the point, where these beds are intersected by the nullah, they turn round sharply to the Westward, or towards the spectator, so that their strike becomes coincident with the course of the gully, in the bank of which their out-crop is seen to the right of the sketch, while to the left fore-ground are the coarse fossiliferous grits, which I have referred to the Ootatoor Group (page 47), and which rest on, and are in part intercalated with the boulder-bed, and dip gently towards the spectator, or at right angles to the overlying Trichinopoly beds.

Between Cullygoody and Kurracoopay.

Following the out-crop of the Trichinopoly beds to the North-west, another patch of the coral limestone is met with at the South of the nullah that drains the Cullygoody valley. It is low and flat, and resembles, in all respects, the limestone of the lower part of the Cullygoody ridge, the streaked coralliferous rock being common both *in situ* and in the boulders of the rock, which are enclosed in the overlying Trichinopoly conglomerates. It is, in fact, the base of a ridge, the upper part of which has probably been denuded. Some limestone is found to the North of the stream, both resting on the boulder-bed, and, as already mentioned, on the gneiss, to the East of Malarasure, but only in small quantity. To return to Cullygoody: the Southern edge of the Cullygoody

East of Malarasure.

ridge terminates somewhat abruptly, and the Trichinopoly beds are exposed in one or two little nullahs dipping away from it usually at a high angle. Adjoining the camping ground at Cullygoody, at a distance of about 200 yards from the main ridge, we meet with another small ridge of limestone on which the village is partly built, consisting, in part, of the coralliferous form of the limestone. A break of about a mile then intervenes, which is occupied by the boulder-bed, and we then come to the Vadoogapaitty ridge, which extends for about a mile to the bank of the Palumbaddy nullah. The rock of this ridge is much concealed by the soil, and the summit close to the village, which is the most elevated point for many miles round, is thickly covered with an isolated patch of ferruginous sand similar to that which occupies the high ground of the Wodiarpolliam jungles. Some of the rock is, however, exposed on the Western slope, and close to the village, the same variation in the character of the rock is observable, which, as I have remarked, obtains elsewhere. The coralliferous form of the limestone occurs only at the base of the ridge, where the corals are very abundant, and the rock massive in structure and honey-combed on the surface. The upper part, on the other hand, exhibits, when viewed on the ground, a decided bedded structure; and when broken, a sub-crystalline fracture, being composed of broken corals, shells, &c., cemented into a compact limestone.

At Cullygoody.

Vadoogapaitty ridge.

Structure of rock.

At the base of this ridge a peculiar rock of a pisolitic structure occurs in great quantity. It is made up of small pisiform nodules, formed by the deposition of successive coats of calcareous matter round fragments of the limestone, and cemented together by similar material, generally into a compact stone, with occasional irregular cavities. It is probably formed in part beneath the soil, where the latter is thin, for, in a section exposed in

Pisolitic limestone.

a small quarry in the Trichinopoly beds, (here also limestone,) I found a layer of the pisolitic rock, about 6 inches thick, beneath the cotton soil, and resting on about 2 feet of little rolled fragments of the different varieties of the limestones.

Mode of occurrence.

The nuclei of the individual nodules are most frequently mere grains, and the nodules from the size of a pea to that of a hazelnut, but sometimes the rock is made up of limestone fragments of all sizes, up to 4 or 5 inches in diameter, and, not unfrequently, masses of the pisolite itself are seen imbedded in a more recent formation of similar nature. This rock, although more abundant here than elsewhere, is by no means peculiar to this ridge. It is met with, for instance, on the Ootatoor limestone of Olapaudy, and to some extent on the Cullygoody ridge. Limestone blocks, both of the coral reef and purer sedimentary varieties, are also occasionally found with a similar calcareous coating one or two inches thick, in which the pisolitic structure is largely seen, and where it is difficult to imagine that any accumulation of calcareous matter could take place mechanically or chemically.

Structure.

That this rock is of sub-aerial and recent formation there can be little doubt, for it occurs, coating the limestones, in situations where no accumulation of water is possible. Moreover, in a specimen presented by Mr. Cunliffe to the Geological Museum, a specimen of *Helix fallaciosa*, one of the commonest living snails of the country, was thoroughly embedded. There is, however, some difficulty in understanding how successive coats of calcareous matter could be deposited round a number of nuclei, so as to form pisolite, if the nodules were not freely suspended in the formative fluid.

Of recent formation.

That the coral-reef limestone of Cullygoody is of the same age as that at the other localities previously described, I infer, for the following reasons:—

Age of the Cullygoody limestone.

1*st.*—It resembles the reef limestones of the Ootatoor Group in all its mineral peculiarities, and of the few recognizable fossils which it contains,

one is certainly identical with a species characteristic of those limestones, while another closely resembles a species from the Ootatoor Group, which is not found in the Trichinopoly beds, and a third (a Belemnite) belongs to a genus which I have only met with either in the Ootatoor Group, or the reef limestones of the same epoch.

2nd.—No coral-reef limestone, that I have met with elsewhere, belongs even probably to any other than the Ootatoor period, nor (except in the immediate neighbourhood of Ootatoor reef limestones) do the conglomerates of the Trichinopoly beds contain fragments of such rock as might lead us to believe in the former local existence of Trichinopoly reefs.

3rd.—The beds on which the Cullygoody limestone rests are of doubtful age, but it is more probable that they belong to the Ootatoor than to any later group, inasmuch as they contain Belemnites, and that the Trichinopoly beds rest on them with greater and more decided unconformity than can be accounted for by local irregularity of bedding. I have shown in the preceding pages that the Ootatoor reef limestone occasionally rests on the first-formed beds of the group.

I lay no stress on the fact that a boulder-bed, such as that underlying the Cullygoody limestone, nowhere occurs at the base of the Trichinopoly Group, inasmuch as the bottom beds of that group are very variable; and if, as I have reason to infer, the boulder-bed at the base of the Ootatoor Group is a remnant of the plant-beds, there would be no *à priori* improbability of its occurring occasionally at the base of the Trichinopoly Group under similar conditions. Neither do I insist with any great emphasis on the fact that neither the boulder-beds nor the associated grits contain any fragment of older sedimentary deposits, while the Trichinopoly conglomerates generally are full of fragments of the Ootatoor beds. Although of some little value as negative evidence, the Trichinopoly conglomerates offer too many exceptions to the above rule, to admit of the absence of Ootatoor pebbles being taken as a criterion of age. I think, however, that in the absence of any evidence to

the contrary, the reasons I have enumerated fully warrant the inference I have arrived at as to the age of the Cullygoody limestone.

General considerations on the origin of the Coral-reef limestone.—In the preceding pages I have entered at some length into the details of the structure, and of the other physical peculiarities of the formation, which I have designated as coral-reef limestone, and I would now explain the grounds upon which I have so termed it, by instituting a comparison of the formation in question with that of the great coral formations of the present day, as described in the able works of Darwin, Dana, Jukes, Nelson, and other authors who have devoted special attention to this subject. It is here unnecessary, and beside my object, to say aught of the external features of fringing and barrier reefs and atols. None of the distinctive superficial features of barrier reefs with their internal and intersecting ship channels fringing reefs, ledges, &c., are recognizable in the fragmentary ridges which alone remain to us, worn down by repeated denudation and half buried in newer deposits. The structure of the reef rock in its several varieties is that which alone concerns us here, and I shall therefore confine myself to those portions of the works quoted which treat especially of this point.

Reasons for assuming this origin.

Original reefs no longer recognizable.

Structure of rock.

To summarize in the first place the characters of the Trichinopoly coral formations. Their general external form is that of ridges extending from a few hundred yards to 3 or 4 miles in length, the ridges in the latter case not being continuous, but broken up into a succession of smaller ridges by intervals of varying width; which interruptions to their continuity existed in some cases certainly, if not in all, previously to the deposition of the Ootatoor beds around. The rock forming the base of these ridges is always massive in structure, sometimes with a conchoidal and splintery, occasionally a granular, fracture, and in the former case not unfrequently containing corals *in situ*, principally thin encrusting species of *Astræa*. The last variety is exclusively confined to the basal portions of the ridge. More massive corals also occur occasionally, as at Maravattoor, and with these are associated large *Nerinæas* in considerable abundance. The limestone of the upper part of the ridges is generally coarser in structure, consisting of calcareous sand, firmly cemented, and frequently full of recognizable fragments of corals, shells, &c. Small unbroken shells also sometimes occur in both varieties of the limestone, but these are exceptional. The sandy form of the limestone presents in a few cases, notably at Cullygoody, a kind of bedded structure, as evidenced by the ranges of the thick slab-like masses which course along the ridge running parallel with its major axis, and dipping towards what

Of Trichinopoly reef limestones.

Form of ridges.

Lower part of ridges.

Upper part of ridges.

Bedded structure.

must have been the deeper water, at angles varying from 8° to 30°: but from its partial occurrence there is good evidence to show that this structure was due to the piling of the sand, which was the original material of the stone, developed by subsequent shrinking, and not to the quiet deposition on a horizontal bottom and subsequent disturbance.

Color of limestone.

The color of the limestone is sometimes almost a pure white, and in this variety patches occur of almost a chalky structure: at other times it is of pale pink, yellow, or cream colored tints, the latter being, apparently in some cases, due to the intermixture of fine argillaceous sediment, at others to subsequent infiltration of coloring fluid. I have only found one or two minute enclosed pebbles throughout the whole formation, these being of quartz or gneiss, and occurring at the base of the ridges. With the exception of the case mentioned at page ——, I have never noticed any of the embedded masses of the limestone itself, such as Mr. Darwin mentions as entering into the structure of the outer portions of recent coral formations. In composition the rock is almost a pure limestone. Three specimens analysed by Mr. Tween, the first from Cullygoody, the second from Tripatoor, and the third from Olapaudy, gave only 3·4 per cent., 4·7 per cent., and 2 per cent. respectively of insoluble matter. The soluble portions of Nos. 1 and 2 consisted of carbonate of lime, with traces of iron and magnesia, and a small quantity of alkali (the amount not estimated). The soluble portion of No. 3 contained 96 per cent. of carbonate of lime, 2 per cent. of iron and alkali, chiefly soda.

Chemical composition.

Comparison with recent coral-reef limestones.

Turning now to the consideration of recent coral formations, let us compare *seriatim* the several characters summarized above: and first as to chemical composition.

An analysis of recent coral sand given by Mr. Dana* is as follows:—

Carbonate of Lime	98·26
Ditto Magnesia	1·38
Alumina	·24
Silica } Phosphoric Acid }	Traces.

My specimens were not tested for phosphoric acid, but the quantity of carbonate of lime, as contrasted with the small percentage of foreign matter they contain, is strikingly close to the composition of the recent coral sand as above given. The magnesia in recent coral rock varies greatly according to Mr. Darwin; one specimen quoted by him having as much as 38·07 per cent. In all cases this must be from some foreign source, probably, as suggested by Mr. Darwin, from sea water, and it can scarcely be regarded as an essential ingredient.

Characters of recent limestones.

The physical characters of the Trichinopoly rock correspond no less strikingly to those of recent reef-rock, as described by the same author. Mr. Dana says, (*Op. Cit.*, page 110) " The coral-

* Dana " On coral reefs."

reef rock is in some parts a coral conglomerate or breccia, made up of fragments firmly cemented. * *Over much larger areas* it is a fine white limestone, as compact as any secondary marble, and homogeneous in texture. It is often free from any traces of organic life, or proofs of an organic origin. Only now and then an embedded shell or some other relic evinces that animals of any kind were living in the seas. The white limestone *breaks with a conchoidal fracture, a splintery surface, and rings under the hammer.* These facts are of great importance in deciding upon the origin of the older limestone strata. Other portions of the rock of less extent are made of standing corals, with the intervals filled in by reef debris, and the whole cemented solid. The latter variety here mentioned prevails in the inner patches growing in quiet waters. The former kind is common about the outer reefs, since large areas in the coral plantation are mere sand. It is still more abundant, forming the bottom among the inner patches or in the lagoons, where the finer detritus is washed by the sea."†

I extract this passage *in extenso*, italicising the most important paragraphs; as it shows more fairly and strikingly than any summary of mine could do, how close is the resemblance between the limestone of Trichinopoly and that of recent reefs. Both the varieties described by Mr. Dana occur in the Trichinopoly formation, the purely *clastic* rock being, as in the case of recent coral reefs, the most prevalent of the two. The pale yellow and cream colored tints of the Trichinopoly limestone are, as I have mentioned, in great part due to infiltration, as is evident from its partial occurrence in some of the specimens; and probably also in part to the admixture in very small proportion of foreign sediment derived from gneiss,‡ but the proportion, as shown by the composition of the specimens examined, is extremely small.

Bedded structure.

The rude bedded structure which I have noticed in the Cullygoody reef, is also noticed by Mr. Dana,§ Mr. Jukes,‖ and Mr. Darwin,¶ in their descriptions of the shore rock of reefs; but in the observed cases the angle of dip never exceeds 8°, whereas in the case of the Cullygoody limestone it is sometimes as much as 30°.** From this description I should infer that the bedded rock in the latter case had been formed under water, where not exposed to any violent breaker action, in which case the angle of slope might be as high or higher than that observed.††

Remarks.

I might, had it appeared desirable, have quoted many more passages from the works of modern voyagers, to show how closely our limestone formation answers to their descriptions of coral rocks, but I think the above will suffice to prove the point.

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* The italics are mine.—H. F. B. † See also Op. Cit., pp. 11—27.

‡ Compare Darwin's description of the rock of Keeling Atol, ("Observations on coral reefs," p. 12,) where parts of the rock are similarly tinted. Also Dana (Op. Cit., p. 31).

§ Op. Cit, pp. 16—17. ‖ "Voyage of the *Fly*," p. 3. ¶ Darwin, Op. Cit., p. 12.

** See ante, p. 64. †† Darwin, "Observations on Volcanic Islands," p. 133.

CHAPTER VI.—*Ootatoor Group.—Ootatoor Beds.*

Extent of Group.

THE Ootatoor Group is the lowest of the three main sub-divisions comprised in the great fossiliferous series of Trichinopoly above the plant-beds. It occupies a strip of country about 30 miles in length, and 3 or 4 miles in average width, in the talooks of Tripatoor and Perambaloor, and extends in a North-east direction from the neighbourhood of the Tehsildaree station* of Tripatoor, to within a few miles of the Vellaur, where it is overlapped by the Arrialoor Group, just before the entire series disappears beneath the great deposits of regur and alluvium which occupy the valley of that river. Along the whole of its western boundary it rests with undisturbed stratification either on the gneiss or on the plant-beds and coral-reef limestone, but on the south, where it abuts against the confines of the Granitic region of Thutchuncoorchy, it is cut off by a system of little parallel faults (briefly alluded to in the foregoing section) and concealed beneath the beds of the Trichinopoly Group. That it originally extended far to the Westward and Southward of its present limits seems very probable, when we regard the lithologic characters of the existing formation, and the evidences of extensive denudation afforded by the abundance of its debris in the conglomerates of the higher groups; no traces of it have, however, been found anywhere to the Westward or Southward of its present area, and on the North-east, in the District of South Arcot, it is equally wanting.

Stratigraphical relations.

Originally more extensive.

Lithological characters.

In lithologic character the Ootatoor beds present much variety. Fine silts, calcareous shales, and sandy clays frequently concretionary, and more or less tinted with ochreous matter, predominate throughout the group; and as far North as Garoodamangalum and Kauray, constitute almost the entire bulk of the

* The chief village of the talook or sub-division in which the Talook Revenue Officer, the Tehsildar, resides.

deposit. To the North of these villages limestone bands become intercalated in the lower or Western part of the group, and sands, grits, and conglomerates in the upper or Eastern part; these changes in mineral character being accompanied by a great enrichment of the fauna in the one case, and an impoverishment in the other. Conglomerates are of rare occurrence in the lower part of the group. Indeed, except in the immediate neighbourhood of the coral reefs scarcely anything that can be called a conglomerate is to be met with in the bottom beds which consist of soft shales formed of the finest sediment, and resting at varying angles and with most irregular stratification, on the uneven gneiss bottom.

Conglomerates rare.

At one point on the Southern boundary between Paroovalapoor and Seraganoor, again to the West of Agaram, and at Cullygoody a boulder-bed occurs, resembling in all respects that at the base of the plant-beds. There is, however, no reason to believe that the boulders have been transported from any distance, and the absence of all conglomerate, and the immediate sequence of the usual fine shales, would lead us to conclude that the bed is a previously formed accumulation of boulders, probably of the age of the plant-beds upon which the Ootatoor beds were quietly deposited.

Boulder-bed not of Ootatoor age.

Gypsum occurs in most of the argillaceous beds, and is to a certain extent characteristic of the Ootatoor Group. I have never met with any interstratified bands of this mineral, or any that could be regarded as of contemporaneous formation. It either forms plates of irregular thickness intercalated in the beds, and filling cracks in the clays and shales with which it is associated, or it is found segregated in concretions, and occasionally replacing the original shells around casts of Nautili, Ammonites, and some of the thick shelled Mollusca. In all cases it appears to have crystallised out subsequently to the formation and partial desiccation of the enclosing strata, and has probably been introduced by waters infiltered from the surface.

Gypsum not contemporaneous.

Stratification.

The stratification of the Ootatoor Group, although tolerably regular on the whole, and exhibiting a general dip to the South-west, presents many anomalies which lead me to conclude that it is by no means due to regular superposition of sediment deposits on a horizontal sea bottom; but rather to the banking of successive layers of sedimentary matter; the dip of which is, with few exceptions, due to the shelving form of the banks on which they were formed. The reasons which have led me to entertain this view will appear in the detailed description of the Geological features of the group, and will be summarised at the end of the section; and I will not therefore anticipate them by attempting an imperfect outline here; but the fact, if admitted, precludes the possibility of forming any reliable estimate of the thickness of the group from the merely superficial data afforded by the present condition of the country.

Due to deposition on banks.

Fauna of Group.

The fauna of the group is a subject upon which I can only speak in very general terms, and from such knowledge as can be gathered during a field survey, and from a cursory inspection of the fossils at the time of their collection.* The subject is, however, one to which I have been obliged to devote some attention, since a certain knowledge of the faunas of the respective groups was absolutely essential to enable me to map the lines of separation, when, as was frequently the case, stratigraphical evidence failed; and as a long period will probably elapse before the description and publication of the entire fossil series can be accomplished, a few words here on so important a subject will not be out of place.

Hitherto comparatively unknown.

The fauna of the Ootatoor Group has been hitherto less known than that of any of the associated formations. Messrs. Kaye and Cunliffe's original collection, described by Professor Forbes, contained no specimens from this group; and as I

* Except in the case of the Belemnites, Nautili, and some Ammonites.

have mentioned in the introductory chapter, Mr. Cunliffe's second collection, which consisted solely of Ootatoor fossils, still remains for description in the Museum at Calcutta. The fauna is, however, exceedingly rich, and is of especial interest as being intermediate in age between the Neocomian fauna of the Valudayur beds of Pondicherry, and that of the newer deposits in Trichinopoly and Verdachellum, some forms of which were described by Professor Forbes.

Characterised by abundance of Cephalopoda.

Its principal characteristic is the abundance and variety of its Cephalopoda, and in this respect it may be held to equal, if not surpass, the remarkable fauna of the Valudayur beds. The forms, however, are nearly all different, and for the most part peculiar to this group.

Affinities of Cephalopoda.

One or two species of Ammonites, and possibly one of Ancyloceras, (Hamites, *Forbes*,) occur both in the Valudayur beds and in those of Ootatoor, but as a rule the Ammonites bear more resemblance to upper Cretaceous species, and are in some cases identical with greensand and even white-chalk forms of Europe. Some few of them also pass through into the Trichinopoly Group, but the number of these does not appear to exceed a very few species.

The specific development of the genus Ammonite is not the only instance of the richness of the Cephalopod fauna. Ancyloceras, Scaphites, Turrilites, (Hamites?) Ptychoceras and Baculites all furnish representatives, but to what extent specifically, I am at present unable to determine. Nautilus also is represented by seven species and a great abundance of individuals, while of Belemnites, (the only Dibranchiate genus,) only three species have been distinguished.

Geological indications of Cephalopoda.

As a whole, the Cephalopoda recall the Gault fauna of Europe more than that of any other sub-division of the Cretaceous series, but this resemblance may depend in part upon the similar (argillaceous) mineral character of the two formations, or in other words, on the similarity of marine conditions. We have,

in the Ootatoor beds, several representatives both of older and newer deposits than European Gault, ranging from the lower Neocomian to the white chalk, and what weight must be attached to these respectively in any attempt to parallelize our Indian deposits with those of the European series, is a point upon which it would be premature at present to offer any opinion.

Other Mollusca.

The remaining classes of the Mollusca, the Gasteropoda, Conchifera, and Brachiopoda, are all well represented, as will be seen by the following provisional generic list, drawn up principally from field notes.* Those, the species of which are numerous, are marked with an Asterisk, a great abundance of individuals is noted by the †.

GASTEROPODA.	CONCHIFERA.
**Rostellaria.* †	**Ostrea.* †
**Fusus.*	**Pecten.* †
Voluta.	*Lima.*
**Natica.* †	*Spondylus.* †
Nerinæa.	*Plicatula.*
Turritella.	*Inoceramus.* †
Turbo.	*Pinna.*
Phasianella.	**Arca.* †
Pleurotomaria. †	*Pectunculus.*
Dentalium. †	*Nncula.*
Cerithium.	*Leda ?*
Patella.	*Trigonia.*
Emarginula.	*Radiolites.*
Cinulia.	**Cardium.*
Acteonella.	**Cytherea.*
Tornatella.	*Teredo.*

BRACHIOPODA.

Terebratula.
Rhynchonella.
Crania.

* For this I am in great part indebted to a field list drawn up by my colleague Mr. C. Æ. Oldham, who devoted himself principally to the collection of fossils. For its correctness I am myself responsible.

The above list is, in all probability, very imperfect, as may be expected from the nature of the materials from which it is drawn up, and it is likely that there are many omissions which will become apparent when the collections are fully examined.* Such as it is however, it is characteristically Cretaceous. The presence of such genera as *Cinulia, Acteonella* and *Radiolites*, and the great abundance of Inocerami, no less than the absence of most genera especially characteristic of Oolitic or Tertiary times fully respond to the indications afforded by the Cephalopoda of the Cretaceous age of the fauna.

Remarks on the above.

Of other forms of life we have many instances. Corals of several species occur in the lower beds, many of them derived from the wreck of the reef limestone, but some also of contemporaneous origin. Of *Annelids* also, there are several species, some of them peculiar to and very characteristic of the group. Wherever they occur, they are always in great abundance, and are very characteristic of certain beds. Of the Crustacea, I have met with no examples. The "Crustacean" remains mentioned as occurring in great abundance (by Dr. Muzzy,) in the Belemnite clays of Ootatoor are, as I have previously mentioned, concretionary nodules, as also are the fossil turtles mentioned by the same observer. The remains of vertebrate animals are also very scarce, the vertebra and teeth of a fish (a shark) and a few bones of doubtful nature being the only instances of their occurrence.

Corals.

Annelids.

No Crustacea.

Vertebrate remains scarce.

* The number of the smaller forms of Gasteropoda and Conchifera will I believe be largely increased on examination. These occur crowded together, and chiefly as casts, in which form they are not easily recognizable on a rapid glance. A more perfect list must be reserved for a work specially devoted to the Palæontology of the Cretaceous rocks; the great mass of fossils on hand precluding the possibility of a re-examination for the mere purpose of improving, not perfecting the above, and the other generic lists now published.

Plants.

Plant remains in the form of drift wood, sometimes bored by the Teredo, abound in certain parts of the group. The wood is cycadaceous and exogenous.

Details of the Geological structure.

With these preliminary remarks we may pass on to a more detailed consideration of the Geology of the group. I have above observed that South of Kauray and Garoodamangalum, the Ootatoor beds consist almost exclusively of laminated sandy clays and argillaceous shales, with comparatively few fossils.

Tripatoor.

Character of beds.

Beds of this character are met with in the broken ground around the coral-reef limestone of Tripatoor, lapping round the highly sloping sides of these ridges, and where the limestone is wanting, resting on the gneiss. The beds are alternations of fine sandy and argillaceous sediments enclosing a few pebbles and blocks of the limestone in the immediate neighbourhood of the reef ridges, but without any regular conglomerate. Many of the finer sediments, which are quite soft and unconsolidated if crushed by a slight pressure between the fingers, split up into flakes of extreme tenuity, a property due to microscopic scales of imbedded mica, aided by very slow original deposition, which allowed these minute laminæ to arrange themselves in an uniformly parallel direction. In common with the Ootatoor beds throughout this part of the country, these deposits are full of kunkur, especially towards their base. This impure nodular carbonate of lime generally fills all the crevices of the beds, and occurs in lenticular patches between them. As in the case of the plant-beds, it is evidently infiltrated subsequently to the deposition of the rocks in which it occurs.

North-west of Seraganoor.

All these beds are quite unfossiliferous. About 100 yards, or less, to the South of the limestone they are covered up by coarse conglomerates and sands of the Trichinopoly Group, which are full of pebbles, both of the neighbouring gneiss and limestone, and of the yellow argillaceous nodules characteristic of the Ootatoor beds a little further to the Eastward. Crossing the rise covered with smooth cotton soil between the Tripatoor and Seraganoor nullahs, the Ootatoor beds are again met with in the numerous little nullahs which drain its Eastern slope. They here begin to assume the ochreous tint and nodular structure characteristic of the finer deposits of the Group, but contain no fossils. With the exception of some sandy bands, they are finely laminated, and almost unconsolidated; and dip at an angle of 15° to 20° away from the Northern boundary.

At Seraganoor.

Unconformity of Trichinopoly and Ootatoor Groups.

North of Seraganoor, the band of Cretaceous rocks increases to about three-fourths of a mile in width, of which the Ootatoor beds occupy the Northern half. The Southern half is occupied by a thin covering of Trichinopoly sands and conglomerates, containing many characteristic fossils, and full of fragments of the argillaceous nodules of the lower beds. The unconformity of the two groups is seen more clearly in this neighbourhood than perhaps elsewhere in the district, and the distinctive lithologic characters of the two groups are unusually well marked. The Ootatoor beds rest apparently on the gneiss of the Northern boundary, and to within a short distance of the Trichinopoly overlap dip irregularly to the Southward. Beyond this the dip is generally in the opposite direction, but the bedding presents many irregularities, and it is at least questionable whether the apparent dip is not in a great measure the result of original deposition. Such is, however, certainly not the

case where the Ootatoor beds re-appear close to the gneiss of Seraganoor. A little gully, about half a mile North of the village, after cutting through some coarse conglomerates and sands of the Trichinopoly group in the upper part of its course, exposes, a few yards lower down, the fine flakey clays of the Ootatoor rocks (the bedding of which is rendered very distinct by some of their intercalated arenaceous bands,) dipping at angles of 80° and 90° and at one spot reversed.* The whole extent of beds exposed in this little nullah does not exceed a few yards, and the disturbance, however intense at this spot, is probably very local. The gneiss occurs *in situ* a few yards to the South of the nullah, and there can be no doubt that the Ootatoor beds are faulted against it, but on following the boundary to the East of the Trichinopoly road, no traces of dislocation are discoverable, and in many places the Ootatoor beds evidently rest undisturbed on the gneiss. At two other points only on this boundary; (first, to the East of the little Trichinopoly outlier of Muddam, the second, in a small nullah about a mile to the North-west of Peria Koorkay,) were there any indications of fracture in the Ootatoor beds; and both of these were quite insignificant in amount, while in the intervals, beds undoubtedly at the base of the Ootatoor Group, are seen resting on the gneiss. In the numerous little sections of Ootatoor beds exposed in the banks of the nullah that drain the high ground round Muddam and Agaram, amid frequent irregularities of dip, I have never observed any case of undoubted fracture or indication of violent disturbance, I am inclined, therefore, to believe that the Southern boundary of the Cretaceous rocks between Seraganoor and Paroovalapoor is formed by several little faults with intervals, in which the Ootatoor beds rest undisturbed on the gneiss. The Trichinopoly beds, which will be described further on, are in all cases quite undisturbed.

Fault at Seraganoor.

Character of boundary to East of Seraganoor.

To the East of Seraganoor the ridge along which the new Madras road runs, is thickly covered with cotton soil, beneath which the Cretaceous rocks are concealed. To the east of this a large area of broken ground, stretching away to Agaram and Paroovalapoor, exposes the Ootatoor beds very clearly, with irregular patches of the Trichinopoly beds as before, along their Southern boundary.

On the Northern boundary the junction of the gneiss and Ootatoor beds is exposed in several little nullahs which cut deeply into the Cretaceous rocks. The latter rest on a highly inclined gneiss cliff, in accordance with which the lowest beds dip, so as to present much of the appearance of faulting. There is, however, no evidence of any disturbance, and the bedding follows the irregularities of the gneiss in such a manner as to prove that its high dip is that of original deposition. At a few yards distance the dip diminishes generally to 2 or 3 degrees, but about half a mile to the South the high dip again obtains, in an opposite direction, or towards North-west and away from the Southern boundary. At the Western extremity of the Trichinopoly outlier of Muddam, the junction of the gneiss and Ootatoor beds is exposed in a little nullah, but the section is not very clear. The latter beds are fine brownish laminated clay, dipping where close to the gneiss, at an angle of only 4° or 5° a dip, which increases to 15° at a few yards distance; close by they are capped with masses of fossiliferous conglomerate belonging to the

Beds to East of Madras road.

* These clays are intersected with irregular lines of a soft white mineral resembling chalk, which crushes readily between the fingers, and proves, on examination, to consist of almost pure carbonate of lime. We shall meet with it again in great abundance in the clays of Ootatoor, where I shall describe it more fully.

Trichinopoly Group. In the neighbourhood of Muddam the Ootatoor beds are somewhat fossiliferous. The flakey gypseous clays which form the mass of the beds, are here intercalated with

Fossiliferous beds of Muddam.

ochreous bands of sandstone and shales, full of fossils, chiefly in the form of casts. The fossils consist of species of *Ostrea*, *Pecten*, *Inoceramus*, *Arca*, *Cardium* and *Corals*, with a few *Gasteropoda* (chiefly *Natica*), and a small free Spirorbiform annelid, very characteristic of the Ootatoor Group. With these occur also a few Cephalopoda (*Ammonites Mantelli*, and *Baculites teres*,) but these latter are not common. The fossiliferous shale beds extend only for a short distance; they then become merged in the great mass of laminated gypseous clays which extend from Agaram Northwards to Terany, and which are either unfossiliferous, or are characterised by fossils of a few species, but abounding in individuals, and almost peculiar to these beds. The Muddam fossils resemble, in association and also in the character of their matrix, those of the Odium beds, about 16 miles to the North-east, a resemblance undoubtedly due to similarity of local conditions at the period of their formation.

In many places the shales, where unfossiliferous, especially the thinner bands, exhibit a

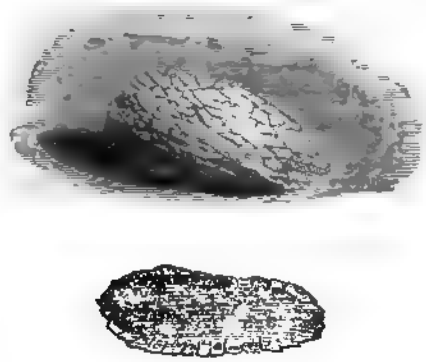
Zig-zag shales.

peculiar zig-zag structure which, like the well known cone-in-cone structure, of which indeed it is a modification, appears to be the result of crystallization; only certain beds are affected by it, as may be seen in many examples:—hand specimens, not more than 6 inches square, often exhibit one half the bedded, and one half the zig-zag structure.* The mineral which determines the formation of the latter is carbonate of lime. Shales of this character occur largely in some parts of the Ootatoor Group, and to some extent also in the Trichinopoly Group, especially in the neighbourhood of Alundanapuram. I have noted them on the map as the zig-zag shales. Another lithological peculiarity of similar origin, and occurring in association with the above, is a shale of loose porous structure, formed of layers of impure fibrous carbonate of lime, with a general horizontal arrangement, which are piled loosely on one another so as to leave the mass full of lenticular cavities of

Concretions.

all sizes. A third peculiar lithological form due to the crystallisation of impure carbonate of lime is that of large concretions (Fig. 7), the surfaces of which

FIG. 7. LARGE CONCRETION IN OOTATOOR SHALES.



* A specimen of this fibrous shale, analyzed by Mr Tween, gave 66·9 per cent. of carbonate of lime. As is the case in the Fontainbleau sandstone, the carbonate of lime appears to have enclosed a large proportion of foreign matter during crystallization.

exhibit gaping cracks in every direction, resembling a half shattered piece of Mosaic work. These cracks, unlike those of ordinary Septaria, are almost confined to the exterior, and appear to be due to the crystallization of the cementing carbonates. Fragments of these concretions closely resemble those of the "zig-zag" shales; they occur both in the upper part of the Ootatoor Group, around Servaluppoor and Alundanapuram, and in the Trichinopoly beds, to the South-east of the latter place.

Between Agaram and Paroovalapoor, unfossiliferous gypseous clays constitute almost the entire mass of the Ootatoor beds. They are usually laminated, and of various colors, tints of yellow, grey, red, and olive-green, each predominating in turn. To the South-west of Agaram these are seen resting on the gneiss without the intervention of any conglomerate or boulder-bed, but on their Southern boundary a boulder-bed or mass of gneiss blocks extends for about half a mile along their base between the Muddam outlier of the Trichinopoly beds and the nullah which drains the area above described.

Beds S. E. of Agaram.

Beyond this nullah but little of the Ootatoor beds is seen, the surface being evenly covered with cotton soil, except where the latter is cut through by one or two little nullahs, in which the sands and conglomerates of the Trichinopoly beds are for the most part the only beds exposed; but on the boundary about a mile to the North-west of Paroovalapoor some laminated clays or rather shales are exposed, which have all the characters of the Ootatoor beds, and which are twisted and broken in such a manner as to induce the belief that they are here faulted against the gneiss. Very little of them is, however, seen, and I could not satisfactorily establish the existence of a fault. Similar beds, characterised as usual by intercalated layers of Gypsum are seen also along the Northern edge of the Trichinopoly beds, and at one place I found a band of blue limestone containing a few fossils. The dip of all these beds, except in the instance above noted, is very gentle, rarely exceeding 6° or 8°, and is generally towards the North-east or away from the gneiss.

Beds North of Paroovalapoor.

Fault.

Dip of beds.

In the country between Paroovalapoor and Ootatoor but little of the rocks is exposed, except along the Western boundary, where they rest on the gneiss or the plant-beds; and at a few points to the Eastward between Paroovalapoor and Servaluppoor, near the overlap of the Trichinopoly Group. The former are soft brown argillaceous silts, with Gypsum and occasionally ferruginous nodules, which appear to have been formerly collected and smelted for iron, as lumps of old slags are not unfrequently met with in the vicinity. These beds are well seen between Agaram and Naicolum. They are quite unfossiliferous. The latter beds are clays and yellow shales, also gypseous, with occasional bands of limestone, all equally unfossiliferous.

To the East of Ootatoor brown and ochreous clay or silt prevails almost to the exclusion of other forms of rock. Looking Eastward from one of the gneiss mounds that front the village, the eye wanders for miles over a low, smooth, undulating tract, unbroken by tree, shrub, or rock, thinly covered with tufts of wiry grass, and seamed here and there with broad muddy nullahs. Far to the Eastward the view is bounded by a prominent ridge of limestone, hereafter to be described, which marks the base of the Trichinopoly Group, while to the North, on the flank of the low ridge which forms the watershed of the Murdayaur, a mass of low rounded mounds simulating as remarked by

Character of country East of Ootatoor.

Dr. Muzzy, the artificial mounds thrown up from excavations, exhibit the characteristic denudation of the soft Ootatoor clays. (Plate I.)

Crossing the narrow strip of plant-beds already described in a foregoing chapter, the base of the Ootatoor Group is met with in a small nullah about three quarters of a mile to the East of the Ootatoor bungalow. The bottom of the group consists of soft brown ochreous clay or fine silt, similar to that which prevails over the country to the Eastward, and resting on the unevenly denuded surface of the plant-beds. It is finely laminated, the laminæ dipping at a low angle to the Eastward, and is cut up in all directions by innumerable layers of a soft chalky mineral, and plates of gypsum running vertically through the mass. Irregular nodules of ferruginous clay, their cracks filled with crystallized Selenite, are also disseminated, and many of these contain *Nautili*, *Ammonites*, &c., the shells of which have been replaced by Selenite. A few other fossils, *viz.*, *Belemnites*, *Lima*, *Terebratula*, *Pleurotomaria*, *Pinna*, and a peculiar conoidal coiled *Serpula** also occur, but the species are few, and many of them peculiar to this neighbourhood. Among the Cephalopoda, Nautili of the *Radiat*-section are most common, and one of these appears to be identical with the European *N. pseudo elegans*, D'Orb., of the Neocomian formation. With this is associated *Ammonites inflatus*, Sow, and a *Hamite* closely allied to, if not identical with, the Gault *H. armatus* of the same author. This association in the same bed of species, peculiar to three distinct and widely separated zones of the Cretaceous formation of Europe, is characteristic of the whole Group. All these species are met with again in the beds around Odium, and the varied fauna there associated with them, fully bears out (so far as I have at present investigated it) the anomalous character, of which we have here an example.

Character of beds.

Fossils.

Anomalous character of fauna.

On the North-east, where, as above mentioned, the clays are exposed by irregular pluvial denudation, these beds present much the same appearance as at Ootatoor. They are brown flaky silts, sometimes sandy, cut up by vertical layers of soft powdery chalk and gypsum, and full of little septaria and radiating veins of impure gypsum. The Septaria are small, generally about the size of an egg or an orange, and almost as regular in form. They are generally rather elongated, and conical or acuminated at the extremities, and apparently owe their form to that of the body which has constituted their nucleus; but after breaking many scores of them, I have never discovered any organism, except in one case, in which a small bone was enclosed, and which was evidently not the nucleus of the nodule. Nodules from the London clay, similar in form to the above, were shown by Mr. Wetherell† to have been formed around the horny stem of a Zoophyte (*Graphularia Wetherellii*), the cast of which he frequently found in the interior. It is very probable that the nodules of the Ootatoor clay may have been formed around some similar organism, the impression of which has disappeared in the subsequent shrinking of the interior, and the infiltration of calcspar and gypsum which fill the cracks of the Septarium.

Septaria nodules.

Belemnites and a few *Nautili* and *Ammonites*, with, in some places, a very small species of oyster, in great abundance, are the only fossils found here, but the former occur in vast numbers scattered everywhere on the surface. The guards are the only parts preserved, and of these I have distinguished three species, but as

Fossils of Ootatoor clays.

* This Surpula is distinct from that which occurs at Muddam, and again at Odium, and is peculiar to these clays of the lower beds, of which it is very characteristic.

† Quar. Journal, Geol. Soc., London, Vol. XV., page 30, 1859.

this part is frequently subject to much variation of form in individuals of the same species, it is difficult to determine specific characters with any certainty.

Abundance of Belemnites.

The occurrence of *Belemnites* in such vast numbers in these clays, and their comparative rarity in the beds to the Northwards, (which are characterized by an abundance of *Gasteropoda* and *Bivalves*,) is quite in accordance with the fact of their prevalence in argillaceous deposits in Europe, such as the Lias, Oxford clay, and Gault, and indicates a relation between the mineral character of the rock and the abundance of Belemnites, one probable cause of which I have endeavored to explain in the appended note.*

The clays are very uniform in character, and show but few indications of bedding, except in the nearly horizontal arrangement of the flaky laminæ of which they are composed.†

Upper beds East of Ootatoor.

They extend to within about a mile of the limestone ridge above alluded to, and then assume a shaly structure, and otherwise become altered in character. The zig-zag and fibrous structure becomes prevalent, and the beds assume a bright yellow tint. The bedding is not very clearly marked, but appears to dip generally a little to the South of East about 10° or 12°. Belemnites and all the fossils characteristic of the clays disappear, and the only organic remains are casts of a species of *Inoceramus*, which in certain localities are extremely abundant. The species is one very characteristic of the Ootatoor Group, and is allied to *I. problematicus*, D'Orb., of the *Craie chloriteé*. Beds of the above character are exposed in the nullahs to the West of Garoodamungalum, and continue up to the overlap of the Trichinopoly beds. Where last seen, on the slope of the drainage ridge to the North-west of the village, their dip turns very decidedly to the South-east, the strike conforming here as elsewhere very closely in direction to the out-crop of the Trichinopoly beds.

Inoceramus the only fossil.

North of Garoodamungalum and Terany.

To the North of Garoodamungalum, or rather of the drainage ridge between that village and Terany, the character of the whole Ootatoor Group undergoes a gradual change. The clays which have hitherto almost exclusively formed the western part of the group become intercalated with sandy beds and shales similar to those above described, while the upper beds become interstratified with coarse sands, gravels, and bands of calcareous grit, which increase gradually to the Northward, until they predominate throughout the higher half of the group. At the same time the out-crop of the group widens out, and in a distance of 4 miles, *viz.*, between Garoodamungalum and Kolokaunuttom, increases from about 2 to 4 miles in width, and in 3 miles more, or in the neighbourhood of Shutanure, to not less than 5 miles. The strike of the upper beds still, however, conforms very nearly to that of the Trichinopoly Group, and as their average dip does not diminish (indeed between

Apparent increase in thickness of group.

* The abundance of Belemnites in the argillaceous deposits of Ootatoor, as compared with the more sandy beds only a few miles to the North, appears to me to be explained not so much by the probability that these animals preferred muddy sea bottoms as by the slower deposition of the former beds. Supposing the animals to have been equally abundant during life throughout the entire area, we should find their remains most densely accumulated, where, in a given period of time, the smallest mass of sediment had been deposited, and on the other hand they would be most sparsely disseminated where large quantities of sediment had drifted together.

† At Numbacoorchy the lamination dipped as much as 15°, I rarely noticed it at so high an angle.

Kolokaunuttom and Shutanure, it rather increases than diminishes), it would seem that the increase in the width of the out-crop is due solely to the increased thickness of the group, a thickness which has more than doubled itself in a distance of 7 miles. That the phenomena are more satisfactorily explained otherwise I shall, however, endeavor to show in the sequel, and in the meantime will return to the detailed description of the beds in question.

Bottom beds at Terany.

A little nullah that runs Westwards into the Western extremity of Terany tank lays bare some of the bottom beds, although to no great extent. They consist of unfossiliferous shale and clay, with intercalations of brown sandstone, and when close to the gneiss a few irregular patches of conglomerate, the latter cemented into great calcareous blocks that range horizontally over the surface. The shaly bands appear to roll somewhat at low angles (5° to 10°) but with no regularity, and as this phenomenon is common in the lower beds, and there only, and is never accompanied by any evidence of fracture, I have every reason to believe that it is owing to irregular deposition and the unevenness of the gneiss bottom.

Conglomerate.

The conglomerate contains pebbles of gneiss and coral-reef limestone, together with a few fossils, *Astræa*, *&c.*, but chiefly undistinguishable, and some small fragments of exogenous wood.

Beds East of Terany.

At this point the boundary is very irregular in outline, owing apparently to what I have above noticed, *viz.*, the irregularity of the gneiss surface on which the beds were deposited. A narrow promontory of gneiss runs in to the Eastward for about half a mile, and at the extremity, which is very steep, and is exposed in some broken ground on the East of the watershed, the Ootatoor beds are seen resting at high angles partly on the gneiss and partly on the plant shales which here crop out from beneath the first-named beds.

Enclosed fragments of plant shales.

This locality has been already noticed at page 42. The Ootatoor beds are clays and shales, without any conglomerate, except that, at one place, some of the shale bands are full of little angular fragments of the soft plant clays, which being softer than the enclosing matrix, are rapidly washed out from exposed surfaces, leaving the shale full of small irregular cavities.

Cause of unequal denudation of plant-beds.

This is almost the only instance in which I have met with fragments of the plant-beds in any of the newer rocks, a fact undoubtedly owing to the slight consolidation of the former, and the ease with which they would be reduced to sand or mud by attrition. The way in which these beds have been denuded from the Southern flank of the gneiss promontory, while they have been preserved in the North up to its extreme point, is undoubtedly due to the protection afforded by it, and indicates that at the period of denudation, *i. e.*, at and previously to the commencement of the Ootatoor period, the prevalent current or wind which determined the denudation at this point must have operated from the South-west.

Fossils and minerals.

The fossils here met with are those characteristic of the Ootatoor clays, *viz.*, a few *Ammonites*, *Belemnites*, and the conoidal Annelid. Kunkur and Gypsum abound as usual. To the Northward, as far as the limestone of Kauray, and for about a mile and a half or two miles to the Eastward, beds of similar character prevail. The dip, when apparent, is irregular, with a general tendency to the East. The loose structure of the beds is very unfavorable to observations on this point, and although surfaces, dipping at considerable angles, are sometimes met with, I believe that they are due

to a kind of irregular jointing, and are rarely or never those of bedding. A case of this kind which I noticed in the bottom beds in the neighbourhood of Maravuttoor is illustrated in the

FIG. 8. APPARENT UNCONFORMITY NEAR MARAVUTTOOR.

Irregularity of bedding at Maravuttoor.

annexed figure. The beds, six feet of which were exposed in the vertical bank of a nullah, were distinctly bedded shales, the laminæ of which were quite horizontal. A solid mass of hard homogeneous marl, with a tolerably flat surface, ran across the nullah, as shown in the section (Fig. 8), and it was only after close examination that I could convince myself that I had not a case of unconformity to deal with. The mass showed no trace of bedding. In the neighbourhood of Ainaveram I noticed in 1858 some large concretions, some of which contained Ammonites of 3 feet and upwards in diameter. I was unable at the time to procure specimens of them, and on returning to the spot at the commencement of the next working season they had all been broken up by the Natives, and the land brought under cultivation, so that I am unable to speak with certainty as to their species. I believe, however, that they were either *A. Gautama*, Forbes, of which species specimens, upwards of 4 feet in diameter, are common elsewhere, or else an Ammonite allied to *A. Varuna*, Forbes, which also attained a large size in the Ootatoor beds.

Higher beds at Ainaveram.

The higher beds which are well seen about Ainaveram contain runs of coarse calcareous grit and sands. These are first met with a little to the North-west of Garoodamungalum, whence they are easily traceable to the North-east (the direction of their strike), gradually replacing the finer beds, until a little to the North of Ainaveram the latter almost disappear.

Change in mineral character of upper beds.

Further North similar beds come in successively lower and lower in the group, replacing the clays and yellow shales, and this change in mineral character is coincident with the entire disappearance of the characteristic fauna of the latter beds; the grits being either unfossiliferous, or characterised by forms, which are in a great measure identical with those of the overlying Trichi beds; the mineral character of the two sets of beds is also identical.

The two divisions of the group present their distinctive mineral and palæontological characters as far North as the high ground between the forks of the Murdayaur nullah, where they begin to blend into each other, but even as far North as Coonum and Andoor, conglomerates and grits are more prevalent in the upper part of the group, and each zone is to a great extent characterised by peculiar fossils.

Limestone at Kauray.

Meanwhile to return to the lower beds. Bands of limestone first appear in these beds lapping round the coral-reef limestone to the North of Kauray. I have already described (page 56) the conglomeratic character of this limestone where it rests immediately on that of the coral reef. Elsewhere it is a compact blue or yellow limestone, the former color being that of the interior where the iron which it contains still exists in the form of a carbonate,

the latter on the exterior, and to the depth of some inches, being produced by weathering and the conversion of the iron into a hydrated peroxide. It contains numerous shells, chiefly of *Pecten*, *Lima* and *Ostrea* in single valves. Two species of the first-named genus are especially abundant, one a small smooth shell, resembling *P. orbicularis*, Sow. is one of the most common and characteristic shells of the group, the other a *Janira*, allied to, if not identical with *Pecten 5-costatus*, is no less common, and is one of the shells which ranges through the whole of the Cretaceous series of Trichinopoly.

Fossils.

The limestones are confined to the lower beds of the group, and to the vicinity of the Coral-reefs as far North as Cullpaudy and Penangoor. They form distinct bands, 3 or 4 feet thick, generally not continuous for any great distance, and are quarried by the natives chiefly for building the small temples, which occur in every village. The beds above the limestones up to the commencement of the sands and grits are kunkuriferous clays and shales, with but few fossils (*Inoceramus* and *Annelida.*) Between Varagapaudy and Sirgumpoor, and again to the North-west of the latter village there is a considerable thickness of gypseous clays and shales (all unfossiliferous) below the limestone. These rest on the plant-beds with very evident unconformity, and appear to dip beneath some little patches of coral-reef limestone which, occur to the North of the Sirgumpoor Nullah, and which are immediately followed by a thick band of the Ootatoor limestone, which crosses the nullah just to the East of the village (page 57). About a mile to the North this limestone band, which has passed into a bed of sand and gravel, appears to lap round over these shales, and to rest on the plant-beds, and finally again passing into limestone, on the coral-reef limestone to the South of Cullpaudy. The unconformity is, however, by no means evident, and from the characteristic mineral character of the bottom shales and their resemblance to those of the Ootatoor beds, I am inclined to regard it as in any case merely a local irregularity, such as I have frequently observed elsewhere, and of which we shall meet with many striking examples in the very irregular deposits of a part of the Trichinopoly Group.

Beds above limestones.

Irregularities of beds at Sirgumpoor.

Near Cullpaudy bands of calcareous concretions, from 6 inches to 1 foot in diameter, begin to appear in the clays, and Cephalopoda of forms not hitherto met with, (*Ammonites Timotheanus*, Mayor; *Ptychoceras*, sp. ? *Scaphites*, sp. ?) are sometimes found enclosed in these. These are the first indications of the rich fauna which becomes so abundant to the North in the neighbourhood of Maravuttoor and Odium, and the appearance of which is accompanied by a considerable change in the mineral character of the beds. Before proceeding to describe this interesting country, however, I will return to the upper beds of the group in the neighbourhood of Ainaveram.

Beds East of Cullpaudy.

The change in mineral character from ochreous clays to grey sand and calcareous grits of the upper beds is very conspicuous to the West and South-west of Ainaveram, owing to the dark boulder-like masses of the calcareous bands that mark the out-crop of the latter, ranging above the otherwise smooth surface of the cotton soil, which covers the softer beds sometimes to the thickness of 12 or 14 feet. The grey sands which constitute the mass of the beds, and in which the calcareous bands have been subsequently formed by concretionary action, consist of the minerals of the gneiss, quartz,

Mineral character of Grits, &c., at Ainaveram.

garnet and magnetic iron, with some grains of black mica : small pebbles of gneiss are also sometimes included, and occasionally, though rarely, fragments of exogenous wood and shells, (Gasteropoda and Bivalves) which, like the beds in which they are enclosed, bear the greatest resemblance to those of the Trichinopoly Group immediately overlying. The beds have a very low dip (2° to 6°) from the point where they first appear North-west of Garoodamungalum to Kolokaunuttom, and as both dip and strike coincide almost exactly with those of the Trichinopoly beds, the two groups are scarcely distinguishable, except by the presence of certain characteristic fossils in the latter, the most constant of which is the *Chemnitzia undosa*, Forbes. A large number of fossils are common to the two groups, (sp. of *Voluta*, *Natica*, *Arca*, *&c.*,) or so closely resemble each other, that the superficial knowledge which I had gained from experience in collecting them, did not enable me to distinguish between them.

Resemblance of Ootatoor and Trichinopoly fossils.

About half a mile to the North-west of Kolokaunuttom, the beds are particularly rich in fossils, many of them of species not met with elsewhere. The fossiliferous rock, which is exposed in a nullah, is a blue limestone crowded with small shells, the most delicate sculpture and polish of which are beautifully preserved; but both from the nature of the species and from the fact that all the Conchifera occur in single valves, I have little doubt that they have been drifted to the position they now occupy. Opisthobranchiate Genera, especially *Acteonella* and *Tornatella*, are very abundant. Also a Natica resembling *N. pagoda*, Forbes, but with a peculiar punctate marking like that of *Cinulia*, and species of *Voluta*, *Fusus*, *Eulima*, &c. Most of these I have not noticed elsewhere, but a characteristic Ootatoor *Inoceramus* is common, and many small bivalves, *Cardium*, *Venus*, *Astarte*, &c., which are among the most abundant species, occur also in the lower beds of the Trichinopoly group. An *Acteonella* also, which is extremely abundant in some spots, and which I have not met with elsewhere in the Ootatoor Group, occurs at the base of the Trichinopoly Group, in the neighbourhood of Cullygoody.

Acteonella beds.

We have thus at this locality, both stratigraphically, lithologically, and palæontologically an apparent passage between the Ootatoor and Trichinopoly Groups, and, as I have above mentioned, were it not for the presence of certain characteristic species in the lower beds of the latter which nowhere occur in the former, and had we not within a distance of 2 miles a striking instance of the unconformity of the groups, we might be led to believe that the passage existed in fact. The Kolokaunuttom beds are the highest of the Ootatoor Group. Immediately to the North of Kolokaunuttom the Trichinopoly beds begin gradually to overlap them, and in the neighbourhood of Shutanure a sudden twist in the boundary of the former shuts off all the higher beds of the latter.

Apparent passage into the Trichinopoly group.

On the slope to the North of Kolokaunuttom, and in the broken ground on the Shutanure side of the ridge, these beds are well seen, consisting of the usual grey sands and prominent calcareous bands, the whole almost without fossils. The sands show much false bedding. As we progress Northwards, beds of this character come in irregular succession lower and lower in the group ; so that in spite of the overlap of the Trichinopoly beds the outcrop of the coarser beds remains of about the same width. The angle of dip is very low on the Kolokaunuttom slope, and is either to the South or a few degrees East of South; but in the nullahs on the Shutanure side of the watershed the bedding strikes round to the North-east, and the dip increases to

Upper beds North of Kolokaunuttom.

about 15°. The only fossils I met with in the Ootatoor beds on this side were *Pecten 5-costatus* and a small *Ostrea (O. columba ?)* and these were thinly dispersed through certain of the calcareous bands.

Higher beds at Shutanure.

Between the forks of the Murdayaur, North-east of Shutanure, the same beds dip East-south-east about 20° and contain a few Nautili, *(N. Huxleyanus)* a species which occurs abundantly in the neighbourhood of Moonglepaudy and Coonum, and also in the Trichinopoly beds above. The beds maintain the same character as far as Audanore, disappearing bed by bed as traceable on the hill side beneath the Trichinopoly limestone.

Divergent strike of higher beds.

It is important to notice that the general strike of the upper beds of the Ootatoor Group does not harmonize with that of the lower, nor is there, as I have before observed, any such variation in the amount of the general dip of the group as would account for this difference, supposing that the whole group had been originally deposited of equal thickness horizontally, and subsequently unequally depressed towards the South-east. The strike of the upper Ootatoor beds between Garoodamungalum and Kolokaunuttom nearly coincides with that of the Trichinopoly group, and is to the North-east, while that of the corresponding bottom beds from Oogalore to Kauray is about North by East, yet the average dip between Oogalore and Garoodamungalum, where the group is narrowest, does not appear to be greater than that between Kauray and Kolokaunuttom; these anomalous features of the stratification are not, moreover, confined to the area I have just described, but prevail throughout the group. I content myself at present with noticing the fact: the deduction which I draw from it, in conjunction with other circumstances, will be seen in the sequel.

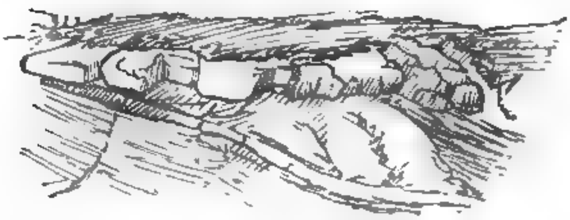
Crossing the North branch of the Murdayaur nullah, we enter upon what is *par excellence* the fossiliferous region of the Ootatoor beds. I have mentioned above that to the East of Cullpaudy we met with the first indications of a richer fauna, in the occurrence of certain forms of Cephalopoda.

Lower beds—Cullpaudy to Maravuttoor.

Between Cullpaudy and Maravuttoor the bottom beds consist of soft shale and clay, with thick bands of yellow limestone, the latter filled with fossils of several species. In some broken ground near the little tank about half way between the two villages some good sections of these beds are exposed close to the gneiss, exhibiting the very irregular bedding which generally characterizes the bottom beds. Owing to the small extent of the sections at any particular spot, and the partial obliteration of their real character by the unequal destruction of the hard and soft beds, the existence of this irregularity is not immediately apparent, and the high dips ranging from 6° to 25°, and sudden twists in the direction of the strike might be attributed to plutonic disturbance. There is, however, no clear evidence of anything of the kind; and the irregular changes and alternations in mineral character remarked when beds are followed along or across their local strike; the absence of fractures; and the fact that the irregularities in question diminish rapidly as we leave the immediate vicinity of the gneiss, convince me that the irregularities noticed are due solely to the formation of banks, by current action and eddies during the deposition of the beds. Of the deceptive appearances often presented by these beds the accompanying sketch (Fig. 9.) of a bed of limestone resting with apparent unconformity upon what appear to be finely laminated clays, gives a fair illustration.

Irregular bedding.

FIG. 9. LIMESTONE ON SHALES: APPARENT UNCONFORMITY.



Appearances of this sort are common, and it is rare that the beds are exposed to a sufficient extent to admit of the deception being detected on the spot. The highest dip that I noticed in any of this false-bedding was 25°, and at only one spot. Most commonly it did not exceed 10° to 12°, and the amount diminished according as it prevailed over a larger area. High dips were very local.

Fossils.

In the limestones of this locality I found several specimens of a species of *Radiolite*, *Corals*, and a large species of *Nerinæa*, *Spondylus*, and several univalves, chiefly casts, which I have not identified. also the plates of a species of Cidaris, almost the only Echinid met with in the Ootatoor beds. Some of the limestone bands are very conglomeratic, being full of fragments of gneiss and of the coral-reef limestone, patches of which rest on the gneiss close by, and it is probable that the Nerinæas and corals, which are the same as those occurring in the coral-reef limestone, are also derived from that formation.

Fossil beds East of Parully.

Similar beds of conglomeratic limestone and calcareous grit, abounding in *Corals*, *Nerinæas*, *Radiolites*, and a large *Pecten* and some fossils more characteristic of the Ootatoor Group, are seen resting on gneiss to the East of Parully, about a mile an a half North-east of Maravuttoor. These beds are very irregular and discontinuous, frequently mere lenticular layers interbedded with white and grey flaky laminated clays, or shales, and fine white sands, also with distinct but probably false bedding. These shales and sands form also the base of the group all round Maravuttoor, and extend for about half a mile to the Eastward. The shales bear a very close resemblance to the plant-beds near Ootatoor, and they are interstratified with sands and penetrated with kunkur in a similar manner, but after repeated search, I found no trace of plants in them.* Mr. Oldham was, however, more successful, and found specimens of plant remains ill preserved indeed, but, as he informs me, still distinguishable, and evidently identical with those of the Ootatoor plant-beds in some of these shales about half a mile to the North-east of Maravuttoor. They are, however, so far as I could make out, inseparable from the Ootatoor beds, and not, as I at first imagined, a patch of the true plant-beds cropping out from beneath the Ootatoor beds. (*See* above, pages 49—52.)

Plant-beds at Maravuttoor.

Whenever the base of these beds is seen they rest at a high angle against the gneiss, at one spot the dip was as much as 45°, but this only where close to the gneiss, and it was evidently due, as in other similar cases, to the high inclination of the rock face on which the bed was deposited. The boundary here twists about a good deal, and the lamination is so irregular, that there appears to be no definite direction of

* To the East of the camping ground they contain several large gneiss boulders which still further enhance their resemblance to the plant-beds.

dip; moreover, about half a mile to the East, a little boss of gneiss, too small to be mapped, but apparently in place, protrudes through the Cretaceous beds to the surface; all bearing out the conviction above expressed, that the gneiss floor of the Ootatoor beds is extremely irregular, notwithstanding its general smoothness where the latter beds have been entirely denuded to the Westward.

Fossils of Maravuttoor beds.

The above described beds are followed to the East and South-east of Maravuttoor by white, grey, and purple banded gypseous clays, with bands of globular concretions, and occasional irregular beds of calcareous shale and limestone, full of fossils, among which the Cephalopoda are very numerous. The Ancyloceras or Hamite previously noticed, at Ootatoor (page 83), a large Turrilite allied to *T. tuberculatus*, Bos., *Ammonites latidorsatus*, Mich., and *A. Timotheanus*, Mayor, are among the most common: *Ammonites Rouyanus*, D'Orb., also occurs here. The first two of these Ammonites are undoubtedly identical with the species of M.M. Michelin & D'Orbigny from the Gault and Craie chloritée of the South and East of France, and of M. Pictet from the Gres-verts of Geneva, and *A. latidorsatus* is one of the commonest species of this part of the Ootatoor Group, where it attains a diameter of nearly eight inches; *A. Rouyanus* is also undoubtedly identical with the Castellane species of M. D'Orbigny, and is one of the few species which is common to the Valudayur group of Pondicherry and the Ootatoor.* *N. Forbesianus*, *Belemnites*, *Baculites*, and several species of Gasteropoda and Conchifera, *Pleurotomaria*, *Rostellaria*, *Natica*, *Pecten*, *Arca*, &c., are common in the same beds.

Thinning out of lower beds to North of Maravuttoor.

The dip of the above beds averages from 12° to 15° E. by S. to E. S. E., and the strike is therefore from two to three points more Northerly than that of the boundary. This variation obtains throughout the Ootatoor beds to the East and North-east of Maravuttoor, and indicates the thinning out of the group to the Northwards. Accordingly when we trace the gypseous clays to the North-east of Maravuttoor, we find that the non-gypseous beds beneath them gradually disappear, together with the accompanying conglomerates and limestones, and in a nullah which flows to the South-east, and cuts deeply across the beds, about 2 miles from Maravuttoor, a mass of obscurely bedded white and purple banded clays, full of lenticular plates of Selenite, and quite unfossiliferous, extends from the verge of the gneiss where it is first exposed to within a half mile of Odium.

Gypseous clays.

Shell limestones.

A quarter of a mile further to the North massive beds of the yellow shell limestone re-appear, dipping, as usual, with great irregularity in the neighbourhood of the gneiss, and covering the high ground with the debris of their out-crop.

Fossil beds around Odium.

Similar limestones, alternating with gypseous clays and calcareous shales, form the mass of the beds to the West, East, and North of Odium, the beds which I have frequently referred to as the richest fossiliferous deposits of the Ootatoor Group. Not less than six species of *Nautilus*, between twenty and thirty *Ammonites*, and three or four species each of *Baculites*, *Turrilites*, *Hamites*, and *Ancyloceras*, and one species of *Ptychoceras* represent the Cephalopoda alone. The Gasteropoda and Conchifera are equally abundant in individuals, and probably also in species, but as they are chiefly in the form of casts, and I have as yet had no opportunity of examining them individually, I am unable to speak to this point with any confidence.

* See Palæontologia Indica, Part I.

The following is a rough field list of the genera found by Mr. C. Æ. Oldham and myself in these beds:—

CEPHALOPODA.	GASTEROPODA.
Belemnites.	*Rostellaria* (Alaria ?).
Nautilus.	*Voluta.*
Ammonites.	*Natica.*
Scaphites.	*Turritella.*
Hamites.	*Pleurotomaria.*
Turrilites.	*Cinulia.*
Ancyloceras.	*Dentalium.*
Baculites.	*Emarginula.*
Ptychoceras.	CONCHIFERA.
BRACHIOPODA.	*Pecten.*
Terebratula.	*Ostrea.*
	Arca.
	Trigonia.
	Inoceramus.

Also one or two *Echinida*, *Annelids*, and *Squaloid* teeth (genus ?). Among the most common of the Ammonites are *A. latidorsatus* and *A. Mantelli*, which species is extremely variable in form and ornamentation. Other species of the Rhotomagensis section are also abundant. A. *Rouyanus* occurs, though sparingly, and also *A. Madraspatanus* n. s. [*M.S.S.*] *A. Julietti*, Forbes, (not D'Orb.) with a few other Pondicherry species. *A. Timotheanus*, Mayor, is not uncommon, and like *A. latidorsatus*, its more abundant congener, is common to the green sands of Geneva. I believe that the majority of the forms will eventually prove allied to or identical with those of the gault and upper green sand, but I have noticed many exceptions, and the very imperfect examination that I have yet made of this most interesting fauna, does not permit me to generalize upon the question of age with any great confidence. The fossils occur sometimes with the shell, more frequently as casts, and except some of the more fragile forms, are for the most part uninjured. Certain bands abound in particular species, especially *Ditrupa* and *Arca*, but for the most part the forms are much intermingled, and the Conchifera almost always occur in single valves; facts which look much as if some at least of the fossils had been drifted into their present position. The Arca bands are chiefly coarse calcareous grits, frequently conglomeratic, and the pebbles as well as the gritty matrix, consisting of gneiss debris, must have required a tolerably strong current to move them. A few layers of similar conglomerate occur at intervals throughout this part of the group, but like the limestone bands, they are rarely continuous beyond a few hundred yards. In one of these bands I found a rib, the only bone met with about here; except that it is probably either mammalian or reptilian, I can offer no opinion as to its nature.

Conglomeratic Grits.

Between Odium on the one hand and Coonum and Permalpolliam on the other, courses of calcareous grits, and conglomerates become more numerous, and several peculiar forms of fossils not met with in the more Westerly beds appear, replacing many of those characteristic of the latter beds. Some of the Cephalopoda

Beds to East of Odium.

of the lower beds, including *A. Mantelli* and *N. pseudo-elegans* occur still, but the majority of the Cephalopoda have disappeared, and *N. Huxleyanus* (a characteristic Trichinopoly form, previously met with in the grits of Shutanure) appears in vast numbers associated with *A. Gautama*, also a common Trichinopoly form, and occurring occasionally in the clays of the lower part of the Ootatoor Group. An *Ostrea*, probably identical with *O. carinata*, two species of *Gryphœa* resembling *G. vesicularis* and *G. columba* respectively, and a Cardium having more resemblance to the living *C. edule* than to any Cretaceous species with which I am acquainted, are, with the large *Arca* previously mentioned, among the most abundant of the bivalves, and with these are associated many smaller forms, *Cytherea*, *Astarte*, &c., which, like those of the Acteonella beds of Kolokaunuttom, strongly resemble, and are probably to some extent identical with, species of the Trichinopoly Group. Among the univalves a large species of Pleurotomaria is very abundant, and the limestones are crowded with *Natica*, *Fusus*, *Rostellaria*, *Turritella*, and *Voluta*, also resembling Trichinopoly forms.

Fauna of upper beds.

Excellent sections of these beds are exposed in the nullahs to the West of Coonum and Permalpolliam, and specially in that half way between the two villages which cuts directly across the strike of the beds. The beds consist of laminated white and pink clays, with bands of fossiliferous shale, limestone, and conglomerate, the whole dipping 8° or 10° to the East. South of this nullah the beds strike round to the South-east as far as Moonglepaudy, and there again turn to the South-west and S. S. W., becoming nearly unfossiliferous beyond Audanore.

Mineral characters of upper beds.

Most of the fossils met with between Audanore and Coonum are confined to the limestones and calcareous shales. The beds of sandy clay which are largely intercalated are here, as elsewhere, comparatively unfossiliferous, and it is interesting, as bearing on the question of drifting, that such fossils as do occur in these finer beds are pelagic Cephalopoda, (Nautilus and Ammonites,) which have probably been originally deposited on those spots where they are now imbedded. *Nautilus Huxleyanus*, *A. Gautama*, (which here attains a diameter of 2 feet and upwards,) two or three species of the Rhotomagensis section of Ammonites, and one apparently of the section Macrocephali, especially characterise certain clay beds, enclosed in calcareous concretions. These specimens are perfect as imbedded, though sometimes slightly crushed, and have the mouth and body whorl well preserved, but owing to the tendency of the concretions in which they are enclosed to split across, they can rarely be extracted entire. Some of the Nautili have the shells very beautifully preserved, exhibiting the finest striæ of growth, but most of the specimens are in the form of casts.

Distribution of fossils according to mineral character of beds.

North of Coonum the distinctive characteristics of higher and lower beds can no longer be traced, and the Ootatoor beds as far as Poothoor, consist of irregular alternations of the various beds I have described, in which we meet with but small and few representatives of the remarkably rich fauna characterising the beds around Odium, and those few indiscriminately distributed. The discordance between the strike of the bedding and that of the boundary of the group still obtains as far as Andoor; the strike of the upper beds being nearly coincident with that of the base of the Trichinopoly Group, while the average dip of the bedding remains pretty constant. The base of the Trichinopoly Group and the Ootatoor beds below are exposed in the nullah North of this village,

Beds North of Coonum.

but beyond this point the demarcation between the two groups cannot be clearly traced, the ridge to the North, which follows the average strike of the bedding, being covered with cotton soil.

Limestones of Assoor and Purawoy.

From Assoor to Purawoy the blue and yellow limestones, short bands of which protrude above the soil and are largely quarried by the natives, are almost the only rocks exposed. They are very full of fossils, chiefly the two species of Pecten noticed at page 87, and a Gryphæa. In the broken ground South of Purawoy yellow shales and clays are seen to constitute the mass of the beds, dipping to the South-east at angles of from 2° or 3° to 15°. At this spot I obtained many of the characteristic Ootatoor Cephalopoda; *N. Forbesianus*, *N. Kayeanus*, *A. latidorsatus*, *A. Varuna*, (*see page* 86,) *A. Mantelli ? A. Gautama*, *Baculites*, *Turrilites*, &c., with a few Gasteropoda, (*Pleurotomaria*, *Natica*, *&c.*,) and Conchifera, (*Inoceramus*, *and Pecten 5-costatus.*)

Fossils at Purawoy.

Conglomerate.

A small patch of coral-reef limestone occurs *in situ* close to the base of these beds, and in a band of conglomerate in the latter close by I noticed several large angular fragments of that rock, some of them containing corals. This is the only instance of a regular conglomerate I noticed about here.

Olapaudy limestone.

From Purawoy to the final disappearance of the group at Vylapaudy, limestone constitutes the mass of the Ootatoor beds. For about a mile to the North of the first-mentioned village, the prominent stony ridge formed by the out-crop of this rock is broken at intervals, the limestone being discontinuous and occasionally replaced by clays and shales, but beyond this the limestone out-crop is almost unbroken. The beds, as seen in some of the shallow native quarries, are thick and massive, somewhat jointed, though not, so far as I could determine, with any regularity in direction. As is usual with the beds close to the base of the group, the dip is comparatively high. In a small native quarry near Vapoor, exposing a section of 7 or 8 feet, the dip was about 20° away from the gneiss; in another small quarry near Olapaudy the dip was similar in amount, while at the head of the little nullah that feeds the Vapoor tank it was 15°. The limestone is variable in grain. Much of it is coarsely granular, and appears to be composed principally of fragmentary shells. In this variety entire shells or recognizable fragments are scarce: the few I have seen in it consist of the Gryphæa (*G. columba?*) Pecten (*5-costatus*) and another allied species: the lowest bands immediately resting on gneiss, sometimes contain a few pebbles of that rock up to the size of a small plum, but there is no regular conglomerate. Another variety of the limestone is finer in grain and sub-crystalline, and the included fossils are likewise rare. They consist chiefly of the above-mentioned species.

Shales at Olapaudy.

Just East of Olapaudy pale grey sandy shales or clays, with strings of kunkur, crop out from beneath the limestone and spread over a large area of ground to the North of the village. In a little nullah which drains the ridge where it is crossed by the road to Cootoonoor, limestone is seen resting on a mass of grey sand, and this again resting on the shales with apparently a slight unconformity of dip. Only two or three yards of the limestone and sand are exposed before these again are covered up by the bottom conglomerate of the Arrialoor group. (*See* Fig. 10.) The shales are again seen in another little branch of the same nullah, a few hundred yards to the North, and on the open ground half a mile North of the village some irregular bands of coarse grey calcareous grit,

FIG. 10. SKETCH SECTION OF ROCKS NEAR OLAPAUDY.

(a) Arrialoor beds, (o', o'', o''',) Ootatoor beds. o', Limestone ; o'', Grey sand ; o''', Shales.

consisting of gneiss debris, and fragments of oyster shells are intercalated in them. Meanwhile the limestone, concealed for a quarter of a mile beneath the Arrialoor beds, strikes away to the N. E. and close to the grits above mentioned, rests immediately on a small patch of gneiss which protrudes between the shales and grits on one hand and the limestone on the other Beyond this the limestone appears to rest on the shales for about 100 yards, and then again on the gneiss. The limestone is therefore clearly unconformable upon the shales ; but I have strong reason to believe that this is merely a local unconformity in the Ootatoor beds, and has not any important stratigraphic signification. I have noticed similar shales apparently irregularly intercalated at the base of the limestone at two or three places between Vapoor and Purawoy. The shales sometimes contain nodules of Jasper evidently concretionary.

Local unconformity of shales and limestone.

Jasper.

The limestone ridge N. E. of Olapaudy is very narrow : it continues to a point half a mile West of Vylapaudy, and then finally disappears beneath the Arrialoor beds, which are exposed in the little nullah running to the West of that village.

Termination of Ootatoor group.

To the North of the village the flat alluvial plain of the Vellaur commences, and stretches away as far as Verdachellum, (20 miles to the North-east,) concealing the older rocks. When the Cretaceous beds re-appear between Verdachellum and Paroor, the Arrialoor group is the only representative of the series, and no older deposits are exposed until we reach the neighbourhood of Valudayur, which will be described further on.

Before closing this description I must briefly advert to the little patch of sands, grits, &c., which are associated with the boulder-bed of Cullygoody, and appear to underlie the coral-reef limestone at that locality. I have already had occasion more than once to refer to these beds, and have briefly mentioned the reasons which have induced me to regard them as of Ootatoor age.

Doubtful beds of Cullygoody.

These beds are best exposed to the North of the main Cullygoody limestone ridge. Close to the extremity of the ridge the boulder-bed is exposed to a depth of 8 or 10 feet in the bank of the little nullah figured at page 65 (Fig. 6), and resting upon it (and shown to the left of that sketch) are some bands of coarse grit full of a large species of oyster, which is very characteristic of these beds.

Passing to the North in the direction of Malarasure we find the boulder-bed and the associated fossiliferous grits cropping out on the surface, or laid bare in the numerous little water-courses which carry off the surface drainage. The boulder-bed occurs at the base of the group immediately resting on the gneiss, and the grits, the materials of which, like those of the boulder-bed, are derived exclusively from the crystalline rocks, project, sometimes in irregular and apparently lenticular masses, sometimes in continuous beds, coursing along the surface of the country. I am unable to offer any estimate of the thickness of these beds ; the dip, where any is seen, is quite unreliable and very irregular in

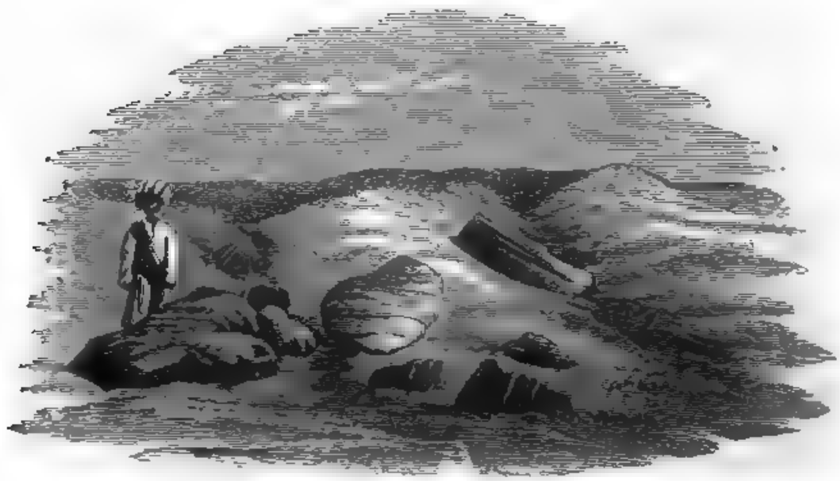
South of Malarasure.

Beds irregular.

direction, except to the North of the principal nullah (see Map), where two beds of conglomeratic grit appear to have a gentle and pretty regular dip to the West. Even here I could not ascertain the amount of the dip, and I think it probable that such dip as exists is due rather to original deposition on a sloping bottom or sub-marine bank than to any subsequent disturbance. The matrix in which the boulders are imbedded is usually a fine sand or sandy shale, composed of the abraded gneiss, but at the spot where the sketch (Fig. 11) is taken, it consists of a fine

Boulder bed.

FIG. 11. BOULDER-BED NEAR MALARASURE.



ochreous clay, resembling that which forms many beds of the Ootatoor Group. The boulders are of all sizes, from 5 or 6 feet in diameter downwards. Of those shown in the accompanying sketch, a nullah bank near Malarasure, the large boulder in the foreground measured 5 feet in length by 4 in breadth, its height could not be estimated, as it was half buried in the sand of the nullah; those lying around were also many of them 3 or 4 feet in diameter.

Sometimes intercalated with the boulder-bed irregular masses of fine micaceous shale occur, having, except in the absence of regular bedding, much resemblance to the plant shales in the neighbourhood of Ootatoor; but I have never found any trace of imbedded plants.

Micaceous shale

The principal interest of this locality is due to the occurrence of molluscous fossils, which are abundant in some of the coarse grit bands The species are indeed few in number, and so far as my memory and a hasty examination in the field enabled me to judge, all, except perhaps a belemnite, peculiar to these beds; but in this I am open to the correction of subsequent comparison. The most common species is a large thick-shelled oyster, which in some spots is so abundant as to form about a quarter of the entire mass of the deposit, and which occurs both entire and in separate valves, more or less rolled. Next to this in importance is a large thick-shelled Trigonia, with broad nodulose ribs, which is abundant only in one bed, but which I have also met with at another locality South of Cullygoody, presently to be described. Of the other species I have only seen

Fossils.

one or two specimens, and these in bad condition, and generally so firmly imbedded in the matrix, that it was impossible to procure them without the expenditure of more time than I could conveniently devote to them. The following list includes all the species here met with.

Ostrea.	1 species, very abundant, apparently peculiar to this deposit.
Trigonia.	2 species, that above described, and a larger species with longitudinal ribs and a smooth posterior area, resembling *T. semisericea*, both peculiar to these beds.
Natica.	1 large species, of which I saw and obtained one specimen only; peculiar.
Ammonites.	1 specimen only seen in section, about 9 inches in diameter.
Belemnites.	1 species, resembling in form and size the *B. stilus* of the Ootatoor Group.

Total, 6 species—Mollusca.

Fossil Wood.

Boulder-bed at Vadoogapaitty.

About two miles South of Cullygoody the boulder-bed is seen in a small nullah close to the village of Vadoogapaitty, and may be traced for about the same distance along the Eastern edge of the ridge of limestone which commences at that village. It is not very extensively exposed, but that it is a continuation of that to the North of Cullygoody, is proved by the occurrence of the nodulose-ribbed Trigonia, in some masses of gneissose conglomerate exposed in the nullah. In the same conglomerate I also found a Belemnite and a small turbinoliform coral, the former resembling the specimen seen in the calcareous grits to the North of Cullygoody, but like it not sufficiently well preserved to be determinable.

I have detailed at page 61—64 my reasons for regarding these Cullygoody deposits, and the associated coral-reef limestone as of Ootatoor age, and need not repeat them here. I shall therefore proceed to summarise the principal facts deducible from the foregoing description with respect to the physical conditions of the Ootatoor Group.

Summary of the preceding.

Age of Ootatoor Group.

THE age of the Ootatoor Group, as compared with the minor groups in the Cretaceous series, acknowledged by European Geologists, is a subject upon which it would be premature to pronounce here. The problem of determining the respective age of minor sub-divisions in distant quarters of the Globe, the intervening area being unknown, or at least imperfectly explored, is at all times one demanding the utmost critical acumen of the Palæontologist for its solution, and until the fossil fauna of the group in question has been

specifically examined, and compared with those of the better known formations of Europe, it would be rash to offer any opinion on its Geological age, beyond that which may fairly be deduced from its *generic facies*, and from a comparison of that *facies* with those of the faunas belonging to the associated groups on the one hand, and to the larger formations of Europe on the other. This comparison indicates that, while it is considerably newer than the Valudayur group of Pondicherry, which has been referred on good grounds to the Neocomian formation, and is older than two groups which have decidedly upper Cretaceous faunas, it has at the same time a notable community of forms with the lower of these two groups, and a smaller number identical with those of the Valudayur beds. We should thus assign it a position about midway in the Cretaceous series, and this general conclusion is fully borne out by the characters of the only order I have hitherto examined at all in detail, *viz.*, the Cephalopoda, the forms of which bear most resemblance to those of the Gault and Upper Greensand, with a certain admixture of Neocomian forms.

Physical conditions of the Group.

With respect to the physical conditions of the formation we are able to speak with much greater confidence, the lithological and zoological indications on this point being numerous. We have seen in the foregoing description that the Southern half of the formation consists almost exclusively of fine silts, with occasional thin bands of sand, but rarely or never, (except in the case of beds immediately around coral-reef ridges,) including anything like a pebble or conglomerate bed. The lowest beds are, for the most part, composed of the same fine materials as the bulk of the formation. The occurrence of a *boulder-bed* at certain spots does indeed seem at first sight to negative this statement, but from the way in which these boulders are crowded together, and their interstices filled with fine silt similar to that which immediately covers them in thin regular

Boulder-bed.

laminæ, I think we must conclude that all such beds are accumulations of boulders previously existing on the land, or remnants of the plant-beds which, in the course of gentle depression, have been gradually submerged, and covered up by the fine silts of the lower beds.* Throughout this part of the formation lime is abundant, principally in the form of calcareous shales, and occasionally of solid limestone: we may also include the lime of the concretions, the Kunkury and Chalky infiltrations which abound throughout the group, as an original constituent of the rocks, which has been dissolved out of the general mass, and redeposited in the interstices of the clays and shales produced by the shrinking of the mass. Of the absolute proportion of lime we can only form an approximate estimate. The *fibrous* shales which are abundantly intercalated throughout the beds, except in the brown Gypseous clays of Ootatoor, contain, according to Mr. Tween's analysis, 66·9 per cent. or not less than two-thirds of their bulk of Carbonate of lime; but it would be probably much too high an estimate to assume the average percentage of lime throughout as anything like this proportion. Even, however, if we assume the average of the lime constituents at one-third this amount, or as forming one-fifth of the bulk of the rocks, an estimate which is in all probability rather under than in excess of the truth, this is still remarkable when we consider how few fossils are found in this part of the formation. We must, I think, look to the coral-reefs, which from their abundant occurrence along the boundary of the Ootatoor beds, we have every reason to believe were originally dotted thickly over the gneiss sea bottom, as the source of the lime so largely intermingled in the fine sediments of the Group. The observations of Mr. Dana on the nature of the sediments around

Abundance of lime in Ootatoor beds.

Source of the lime.

* Or it may be that they are the debris of the local gneiss, which has frequently a tendency to weather into spheroids. Were the gneiss so decomposed to be subjected for a short time to a denuding force, the decomposed sandy matrix would be washed away, and the undecomposed included masses would form a local accumulation of boulders such as constitutes the boulder-beds at the base of the plant-beds and Ootatoor Group.

islands fringed with coral reefs* have an important bearing on this point, and show conclusively that in such localities the tidal and other marine currents frequently bear away for considerable distances sediments composed of the debris of the coral structures intermingled in all proportion with those derived from the neighbouring land.

Fauna of Southern area.

We have seen that a large part of the Southern half of the Group is nearly unfossiliferous, and such fossils as do occur are for the most part swimming or pelagic forms of Cephalopoda. The chief exception to the rule are the Inocerami of the beds near Garoodamungalum and Alundanapuram, the little species of oyster which occurs in great abundance in a restricted area to the East of Ootatoor, and the few turbiniform annelids to the East and North-east of the same locality. All these, I can entertain no doubt, are either *in situ* or have been drifted to a short distance only, seeing that they occur abundantly in particular spots, and there only, and are either unmingled with other forms, or are mixed with such forms as are undoubtedly of swimming and creeping habits, and therefore likely to have reached during life the spot where we now find them imbedded. A mixed fauna, resembling that to the North, occurs only at one spot (Muddam), and the coarser nature of some of the beds at this locality, as well as their higher angle of dip, (a point on which I shall enlarge presently,) coincide with the fossils in indicating the operation of a local current at this spot.

Characters of Northern deposits.

Passing Northwards we have seen that beds of coarse sediment, composed almost exclusively of gneiss debris, first make their appearance in the upper or latest formed beds, and become successively intercalated lower and lower in the series as we proceed further in the same direction ; while bands of limestone gradually increase in number and thickness in the lower part of the formation. *Pari passu* with this change in the character

* See Dana on Coral reefs and Islands, 1853, page 14.

of the deposit is the change in that of the fauna, and while Cephalopoda increase greatly in the number and variety of their forms, they are intermingled in all proportions with Gasteropoda and Conchifera, drifted together in immense numbers. In the coarsest beds, indeed those in which pebbles of gneiss are abundant, fossils are comparatively rare. Beds of moderately fine sand or argillaceous sand and limestone (originally calcareous muds) are on the whole the most fossiliferous. In these beds, then, we have evidence of a very different state of things to that which prevailed to the Southwards. The materials of the Northern deposits were brought down by currents, bringing, together with the sand and argillaceous matter which form the bulk of the deposit, large numbers of shells from the bottom over which it passed, and occasionally pebbles of gneiss and limestone which were drifted along the bottom to a distance of some miles. These coarser materials, rare at first, became more and more abundant, as, with the accumulation of deposits, the sea became shallower, and the transporting power of the current consequently stronger, and encroached continually on the area to the Southward to which fine sediment alone had been previously carried. That Cephalopodous forms, especially ground feeders (tebrabranchiata) should be more abundant here than to the Southward is only what we might expect from a consideration of their habits, as they would naturally most abound *(cœteris paribus)* where those animals were most abundant upon which they depended for a supply of food.

Fauna.

Mode of accumulation of deposits.

These deductions being accepted, we have next to consider from which direction the materials of our deposits were derived, and for this purpose we must first summarise the facts of the bedding, and see how far this structure has been influenced by the operation of marine currents. We have to consider whether the phenomena observed are best explained by original irregular deposition,

Indications afforded by the bedding.

or by horizontal deposition and subsequent disturbance, or by the successive operation of current action and tilting. This question is one which, in most cases, it is sufficiently easy to solve. When extensive and clear sections of a series of beds are exposed, it is generally an easy matter upon mere inspection to detect false bedding, from the absence of parallelism which is perceptible in the structure when a large surface is open to view. In the present case, however, no such sections are obtainable, a few square feet of rock exposed here and there, in nullah banks, being for the most part the only sections available to the Geologist, and when, as in the case of the nullah to the East of Odium, a tolerably continuous section of the beds of from 6 to 20 feet in depth can be followed for any distance, it is found that, with some slight exceptions, the lamination is on the whole so regular that there is no good reason to infer that it is other than that of regularly formed beds subsequently tilted up. The bottom beds do indeed, as I have already observed, offer many evident and undoubted cases of irregular deposition, as proved by their high and shifting dip, and by the absence of any evidence of disturbance either in the rocks themselves or at their boundary against the gneiss where such could be easily detected.

Irregularities of lower beds not due to subsequent disturbance.

This absence of faulting, (with the single exception noted,) along the entire boundary, is of itself sufficient argument against referring sudden changes in the dip of the lower beds to violent local disturbance at a period subsequent to their deposition, since, however the soft Cretaceous beds might yield to any great local strain, the rigid gneiss immediately below would certainly show some signs of fracture, but this consideration is by no means sufficient to prove that the general dip of the bedding to the East or South-east has not been brought about by an uniform elevatory movement to the West and North-west, and unaccompanied by any violent local disturbance. If, however, this had been the case, we should expect to find that the bedding, unless cut off locally

by great longitudinal (N. E. and S. W.) faults (of which I have nowhere discovered the slightest indication,) would preserve a general parallelism to the boundary, at all events as regards the higher beds which could not be much affected by irregularities of the gneiss sea bottom.

Proof of unequal deposition derived from divergent strike of bedding.

But this, as we have seen in the foregoing description, is by no means the case. A glance at the maps will show, *e. g.*, that the strike of the highest beds seen may be followed from Garoodamangalum, where the entire out-crop of the group is only a little more than 2 miles wide to near Ilpagoody, where it has increased to more than 5 miles, and this in a distance of 7 miles, while the average dip of the beds remains almost unchanged, and indeed that of the higher beds is highest where most distant from the boundary. Again, further to the North, the out-crop of the group contracts rapidly, while the overlap of the upper beds is very small, so that in a distance of 8 miles from the line of widest extension beds, which at the latter point are between 4 and 5 miles from the boundary, approach to within 1 mile of it, the average dip remaining, as before, unaltered. Now supposing the beds to have been originally horizontal, and their inclination due to unequal elevation, and taking the average dip throughout at 8°, we should have a thickness in round numbers of 730 feet only at Garoodamungalum, and at Ilpagoody a thickness of not less than 1,900 feet or an increase of 1,150 feet in 7 miles ; and again, in a further distance of 8 miles this thickness would have diminished to rather less than 400 feet, a degree of variability which cannot be admitted in a horizontal formation of such thickness.

Phenomena best explained by the hypothesis of a sediment bank.

If, on the other hand, we suppose that the inclination of the bedding is that of original deposition, the phenomena are simply explained by the supposition that the deposits are those of a great bank stretching along the old Cretaceous shore, and that between Ootatoor and Maravuttoor,

where the formation is at its greatest width, a current coming from the North-west, or from the direction of Perambaloor brought down a larger supply of sediment than accumulated elsewhere. Now this direction is that of the North flank of the Patchamullies, a hill group, which, as I shall presently show, must have existed previously to the commencement of the Cretaceous period, and the general outline of which we may well believe to have been about coincident with that of the Cretaceous shore line, and thus the greater accumulation of sediment, in the area I have indicated, is the natural result of the existence of a long shore current from the Northward, which here leaving the land (indicated by the outline of the hills) deposited the suspended and drifted sediment in the deeper waters of the sea beyond in the form of a great bank. Upon this hypothesis we see why we should have a great accumulation of sub-littoral forms of Mollusca, &c., in the Northern half of the area, while they are almost absent to the South, where comparatively still water prevailed, as indicated by the fine sediments composing that part of the group.* We see also how, as the bank advanced further and further seaward, the sea above it becoming gradually shallower by its formation, coarser materials should be constantly swept further outwards and gradually gain on the area of the finer sediments as we have seen

* The physical geography of the coast of Tanjore and Northern Ceylon exhibits a state of things in some respects analogous to that which I suppose to have obtained in the Trichinopoly area during the Ootatoor period. A great current with a velocity during certain periods of the year, of 4 or 5 miles an hour, sweeps up or down the coast, the direction changing with that of the monsoon, and the deposits along this shore line are sands with numerous drifted shells of sub-littoral species which are washed up in great quantities on the strand. Meanwhile the bay to the South of Point Calimere is, at all times, comparatively still water, and, as I am informed by Mr. Cadell, a great bank of the finest mud is here formed and is gradually silting up the bay. During stress of weather ships lying off Negapatam and neighbouring roadsteads frequently run into this bay and are thus quite sheltered. Now if this current were perennially from the North, Ceylon non-existent or at twice its present distance, (for the mountains of Ceylon formed in all probability an island of the Cretaceous epoch,) and Point Calimere, a rocky headland instead of an alluvial sandy flat, we should have the hypothetical geography of the Ootatoor period exactly reproduced.

evidenced by the gradual extension of the grits and conglomerates of the upper beds to the Southward.*

Amount of dip not discordant with this view.

The hypothesis of banking by marine currents accords perfectly well with the phenomena of strike and dip as regards direction; but before we can consider this hypothesis warranted by the facts, it is necessary to assure ourselves that the amount of the dip is in no case greater than may fairly be attributed to this mode of accumulation. I find, on reviewing my notes, that except at the base of the group, where the bottom beds sometimes rest at an angle of 45° on the highly inclined surface of the gneiss, the highest dip I have observed was one of 30°, and that only in one spot. The grit beds in the neighbourhood of Shutanure are those which have the highest continuous dip, and it there averaged 20°, increasing in some spots to 25°, but this high dip did not prevail beyond a mile or a mile and a half, and is the only instance of the kind met with. Angles of 8°, 10°, 12°, and 15° are prevalent throughout the group, and with these dips the beds are frequently continuous for one or two miles, both along and across the strike, except, in the case of the bottom beds, which, as I have stated, are, on the whole, very irregular. Now the highest of the above dips (30°) is less by 10° than the observed inclination of banks of sediment in the West Indian Archipelago† and is also less than

* Mr. Darwin has shown that although marine currents have not under ordinary circumstances sufficient force to drift pebbles along the sea bottom, yet that pebbles are widely distributed over sub-littoral sea-bottoms. In explanation of this fact he adopts a suggestion of Professor Playfair's, that the undulations of the sea during heavy gales may have power to lift loose bodies of no great size at considerable depth. His observations show, however, that such movements can take place but rarely, and we might therefore expect that the accumulations of a bank formed by a current bringing down fine and coarse sediment mingled, would at some distance from shore contain but few bands of conglomerate in proportion to the other materials.

† *See* Darwin, "Observations on Volcanic Islands, &c.," page 133, and the Appendix to the "Structure of Coral reefs," by the same author, page 196. The observations are founded on information afforded to the author by Captain B. Allen.

that of the escarpment of the Blue Mountains of Sydney, which Mr. Darwin regards as a great upraised bank. Mr. Darwin, in the works I have quoted, does not mention the nature of the sediment, banks of which stand at the high angles of 40° and upwards, but we may notice, as in accordance with the well known rule, that the coarser the material, the steeper its slope of equilibrium, that the beds of the Ootatoor Group which have the highest continuous dip, are precisely the coarsest in the formation.

Ootatoor Group comparatively undisturbed.

Reviewing the whole of the above argument, there can be, I think, but little doubt that the great mass of the Ootatoor beds have been almost undisturbed since the period of their deposition. The fault or faults that cut off the beds to the South are, I believe, extremely small in amount, so much so that they might have been quite overlooked, except for the amount of tilting the beds exhibit at one spot where they are close to the wall of the fault. On a first hasty examination I believed the disturbance to be much more important, and hence the erroneous note inserted in my Report on the Nilgiri Hills.* But that the disturbance in question had any connection with the upheaval of the great hill groups is, I am now convinced, quite out of the question; for any upheaval of such hill masses must necessarily have been evidenced by extensive faulting over a wide surrounding area. These hills must have stood, as they now stand, somewhat higher, it may be, and with smaller gaps and shallower valleys forming the land bordered by the Ootatoor sea. That any great change of form beyond that due to the perennial wasting of winds and waters has touched them, we have no reason whatever to believe, and this fact once admitted, we may assume with great probability that within the same period no part of Southern India has undergone any great convulsion.

The neighbouring hill groups therefore pre-existing.

* Memoirs Geological Survey of India, Vol. I., page 283.

CHAPTER VII.—*Trichinopoly Group.*

Extent of group.

THE Trichinopoly group, the middle sub-division of the Cretaceous series, in the Trichinopoly district, is, like the Ootatoor group, confined to that district where it occupies a narrow strip of country between the Ootatoor and Arrialoor groups. Its greatest width, 3½ miles, is near its Southern extremity, where, overlapping the faulted boundary of the Ootatoor beds, it rests immediately on the gneiss, extending down to the alluvial plain of the Cauvery.

Relations to other groups.

Its width diminishes gradually as it stretches Northward; thinning out, and not apparently overlapped, until we lose all trace of it beneath the cotton soil in the North of the district, beyond which we find the Arrialoor group resting on the Ootatoor beds. It is therefore distinctly unconformable to the Ootatoor group, but it is not strikingly so except at its Southern extremity, where the latter group had suffered some disturbance in the interval preceding the formation of the Trichinopoly group; while with respect to the Arrialoor group no decided unconformity of bedding is to be detected, owing possibly to the want of good sections at the junction of the two. The distinction between them rests at present solely on the evidence of the fossils, coupled with the fact that the Arrialoor beds extend beyond the Trichinopoly group, and rest on the gneiss at both extremities of the latter group.

Physical conditions of deposits of Southern part of group.

The Trichinopoly beds are, even more characteristically than the Ootatoors, the deposits of a shallow sea. As far North as Garoodamungalum, the stratification presents the greatest irregularity; an irregularity evidently due to the shifting of currents, and yet, owing to the fine and regular lamination of the beds over large areas, most puzzling to the Geologist, who, having followed an apparently regular series of stratified deposits for a distance of a mile or more, suddenly meets with

an inexplicable unconformity which baffles all his attempts to trace it out, and which is yet of such magnitude, that it is only after the constant repetition of such failures, that he can convince himself that he has to deal with the local irregularities of a drifted deposit. The difficulty of gaining a clue to the real state of things is the greater that, in the area within which these irregularities are the greatest, fossils are scarce, and those met with are by no means characteristic, belonging to such species as are either common to other groups, or so closely resemble Ootatoor and Arrialoor species, that without a more critical knowledge of them than can be gained in the field, it is impossible to accept them with confidence as indicative of the Trichinopoly group. As regards lithologic character, there is but little to distinguish these from the underlying Ootatoor beds, or from the lowest beds of the Arrialoor group, except in one peculiarity, which the conglomerates of the Trichinopoly series have in common with the Arrialoor beds, but which is not met with in those of the Ootatoor group.

Lithological characters.

I have described in a former place * the granitic band which runs along the North boundary of the Cauvery alluvium. Of the rocks composing this ridge, I have, with a single exception,† never met with any fragments in the conglomerates of the Ootatoor group, which consist exclusively of the debris of the gneiss and coral-reef limestone, and it is probable on this, as on other grounds, that the Ootatoor sea therefore stretched far up the present Cauvery Valley, and that if the granite was exposed anywhere in the land of the epoch, it must have been too far

Peculiarity of Trichinopoly and Arrialoor conglomerates.

* See ante, page 30-31.

† In a thin band of sand intercalated in the shales near Muddam, some minute fragments of quartz and felspar resembling those of the Thutchuncoorchy granite were met with. This band was close to the base of the Ootatoor beds, and it is probable that when it was formed, some portion of the granite remained unsubmerged. The fragments were very small and much rolled. With this exception, the remark in the text holds good for the whole of the Ootatoor group.

away to the Westward, to admit of recognizable traces of it being carried to the existing deposits of the area. The faulting which occurred at the close of the Ootatoor period, must have brought this ridge above the level of the sea; and accordingly the conglomerates of both the Trichinopoly and Arrialoor groups are full of pebbles of felspar, quartz, and the granite itself, and also of the highly foliated hornblende schists, which are associated with the granite, and do not occur elsewhere in the neighbourhood. In the two later groups also we find frequent masses of loose unstratified gravel, composed almost exclusively of granitic debris; and in some places beds of rolled pebbles, almost without any admixture of finer materials, composed of the quartz of this rock, mixed with gneiss pebbles, and closely resembling in its features of accumulation an ordinary recent shingle-beach. The greater part of the Trichinopoly beds, however, consist of fine sands and clays, with infiltrated kunkur, much resembling those which constitute some of the Southern Ootatoor beds, and bands of limestone of the different varieties met with in the Ootatoors are also occasionally intercalated, though less common.

Characters of other rocks.

Between Alundanapuram and Garoodamungalum, or rather in the country to the East of these places, the beds begin to assume a definite strike parallel to the longitudinal axis of the group. Regular bands of shell limestone become intercalated in the lower beds, and hence to the Northern termination of the group, regularly stratified alternations of sands and sandy clays and shales, with bands of shell limestone, calcareous grit, and conglomerate constitute the whole of the group, with unimportant exceptions.

Northern part of group.

The fauna of the Trichinopoly group is, as we might expect from the peculiarities of its stratification, characterised by an abundance of shallow water forms. Many of these are already well known from the collections of Messrs. Kaye and Cunliffe, described by Professor Forbes, and, as I have remarked in a former

Fauna of Trichinopoly group.

place, many of the species, described in that Memoir as from Verdachellum, are really from the Trichinopoly group, which does not occur at that place. I give in the appendix a list of those species which I have ascertained to be thus erroneously referred, together with those described in the same Memoir, and correctly ascribed to Trichinopoly; and I here append a generic list of Trichinopoly fossils collected by the Survey, (with some additions from Professor Forbes' list,) which, as in the case of the Ootatoor list previously given, is drawn up from field lists, and can therefore only be regarded as provisional.

VERTEBRATA.

Pycnodus }
Ptychodus } teeth.

ARTICULATA.

Crustacea, claws, &c.

Annelids.

Spirorbis ? (a coiled free Annelid.)

Serpulæ.

MOLLUSCA.

Cephalopoda.

Nautilus. †
* *Ammonites.* †
Turrilites.

Gasteropoda.

Strombus.
* *Rostellaria.* †
Murex.
Fasciolaria ?
Pyrula. †
* *Fusus.* †
* *Voluta.* †
* *Natica.* †
Chemnitzia. †
Cerithium.
Turritella. †
Scalaria.
Rissoa.
Nerita. * Forbes.
Turbo.
Phasianella ?
Trochus.

Brachiopoda.

Terebratula. †
Rhynchonella. †

Conchifera.

Ostrea.
Pecten.
Lima.
Spondylus. †
Plicatula.
Inoceramus.
Pinna.
Modiola.
* *Arca.* †
Pectunculus.
Trigonia.
* *Cardium.* †
Cyprina.
Astarte.
Opis.
* { *Venus.* } †
{ *Cytherea.* }

Pleurotomaria.
Dentalium.
Tornatella. Forbes.
Acteonella.
Ringicula ? Forbes.

Artemis. †
Mactra ?
Tellina.
Psammobia ? Forbes.
Solecurtus.
Corbula ?
Thetis, [*Poromya*] Forbes.
Panopæa.
Pholadomya. †
Teredo. †

RADIATA.

Corals.

PLANTÆ.

Cycadeous ? and Exogenous ? wood.

In the above list the genera of which species or individuals are abundant, are marked with an (*) or (†) respectively, as in the case of the Ootatoor list. As compared with the latter (given at page 77) the above list shows a considerable decrease in the genera of Cephalopoda, a decrease which is equally apparent in species and individuals. Thus Nautilus is represented by only two species, one of which is common to the Ootatoor group ; and of the nondiscoid Ammonitidæ, I have only noted one or two fragmentary specimens of doubtful genus. Ammonites are more abundant, some of them, *e. g.*, *A. Gautama*, common to the Ootatoor beds, but the species and individuals are much less numerous than in the Ootatoor beds. Some also, as *A. Sugata*, Forbes, are common to the Arrialoor group. Most of the species belong to the section Ligati, others to the Compressi, Rhotomagenses, and Cristati, all characteristic upper Cretaceous divisions of the genus. On the other hand, as compared with the Ootatoor fauna, Gasteropoda and Conchifera are more abundant, both in genera, species, and individuals ; and include some genera, as *Strombus, Murex, Pyrula, Fusus, Voluta, Scalaria, Venus, Artemis, Tellina, &c.*, which are rather characteristic of Tertiary and recent times, and of warm climates. On the

Remarks on fauna.

* Those genera to which Professor Forbes's name is affixed are given on the authority of his Memoir, as I have either not met with them, or have omitted to note their occurrence.

other hand, *Opis*, a genus not met with in the Ootatoor Group, is essentially Mesozoic, and the Cretaceous *facies* is fully borne out by the abundance of *Rostellaria*, and the recurrence of *Pleurotomaria, Acteonella, Inoceramus* and *Trigonia*, in smaller numbers. Among the Brachiopoda, *Terebratula* and *Rhynchonella* are still the only genera, and I have only noticed one species of each, but these, in the one or two localities where they occur, are in vast numbers, offering a great contrast to the heterogeneous assemblage of species which characterizes most of the beds.

Fossil flora.

The fossil flora of the Trichinopoly beds is, like that of the associated groups, remarkable for the preponderance, if not the almost exclusive occurrence of exogenous or cycadeous forms, as indicated by the wood which is abundant in the lower beds of the group, and is met with in drifted logs of many feet in length. I have not noticed a single undoubted specimen of endogenous wood among the numerous specimens noticed in the field.

Details of the Geological Structure.

Outliers at Seraganoor, &c.

In describing the Ootatoor beds in the preceding pages, I have frequently alluded to the outliers of Trichinopoly beds which range along the Southern faulted boundary of the Ootatoor group, between Tripatoor and Paroovalapoor. These beds consist for the most part of coarse unfossiliferous sands and conglomerates, with large included boulders of gneiss, all evidencing shallow water, and breaker action, as the conditions of their accumulation. They cover the extremity of the Ootatoor beds to within a few yards of the coral-reef limestone of Tripatoor, and the bottom bed on their Northern out-crop is a coarse conglomerate full of blocks of the limestone, and of the cream-colored concretionary clay nodules of the Ootatoor beds. A good section of these beds is seen in a small nullah that crosses their strike obliquely near the Western extremity, exposing thick beds of sands, with pebble-beds, and thin partings of fine silt without fossils. The ridge between the Tripatoor and Seraganoor nullahs is covered with blocks of conglomerate belonging to these beds, and in a small nullah to the North-west of Seraganoor their base is exposed, resting on the gneiss at an angle of 25°. In the bed of the large nullah close by some large boulders of the local gneiss (a schistose hornblendic rock) are seen imbedded in this conglomerate with fragments of the Ootatoor beds. One of these boulders, which I measured, was not less than 12 feet in length.

Fossiliferous conglomerate North of Seraganoor.

Again in a little nullah half a mile North of Seraganoor, that mentioned at page 79, a pebble conglomerate of the Trichinopoly beds is seen resting on the vertical silt of the Ootatoors, and the ground beyond for about half a mile to the North is covered with blocks of calcareous grit and conglomerate, containing a

few corals and some of the characteristic Trichinopoly fossils. I also noticed a few small bones in one block, but the matrix was too tough to permit of my detaching the specimen, which, moreover, was not sufficiently well preserved to render it likely that its character could be satisfactorily determined. The Northern out-crop of this outlier is seen in another small nullah, where the bottom bed consists of fine silts resting on the highly inclined Ootatoor beds.

Fossiliferous conglomerate at Muddam.

A quarter of a mile to the East of the Madras road, a fossiliferous conglomerate similar to the above is again met with, resting on the fossiliferous shales of Muddam, described at page 61. In this conglomerate I found several of the most characteristic species of the Garoodamungalum limestone, *Strombusco ntortus*, Sowerby, *Chemnitzia undosa*, Sow. sp., *Cardium Hillanum*, Sow., and some others. This conglomerate is very limited in extent, and the mass of the outlier, of which it is the termination, consists of coarse sand and gravel, containing pebbles of quartz, granite, and gneiss, and some boulders of the latter rock, several feet in diameter. The beds, notwithstanding an occasional appearance of dipping, must be nearly horizontal, and deposited on an uneven bottom, as I noticed gneiss to all appearance *in situ* protruding in the midst of them, upwards of a hundred yards from their boundary. This outlier is not more than three-quarters of a mile in length, and an interval of about the same distance separates it from the next, which commences a quarter of a mile to the West of the Naicolum nullah, and extends down to its bank, as indicated by the blocks of conglomerate that protrude above the soil. No sections are seen, and no distinct bedding, and it is probable that the deposit is quite superficial. In the nullah, which is broad and shallow, nothing but Ootatoor beds are exposed. A few yards above the opposite bank the characteristic gravel and conglomerate of the Trichinopoly beds re-appear and cover the ridge that separates the Naicolum nullah from that of Paroovalapoor. At their Northern extremity, on the Eastern slope of this ridge, a thick band of conglomeratic blue limestone forms the bottom bed, and is seen resting on the Ootatoor shales, in which, about a hundred yards to the Eastward, a limestone exactly resembling the above is intercalated. Both limestones contain a few fossils, *Dentalium*, *Natica*, &c., but the only species which I recognized as characteristic, was *Chemnitzia undosa* in the Trichinopoly bed. Between this point and Paroovalapoor there is much difficulty in separating the two groups.

Irregularity of bottom.

Outliers between Muddam and Paroovalapoor.

Deceptive dip of beds N. W. of Paroovalapoor.

Fine laminated silts, closely resembling those of the Ootatoor beds, become largely intercalated in the Trichinopoly beds, replacing the sands and gravels; and the apparent dip of the beds, wherever seen, is so nearly the same in both cases, *viz.*, at a low angle to the Northward, that I was long puzzled how to reconcile these appearances with the known facts of superposition elsewhere.

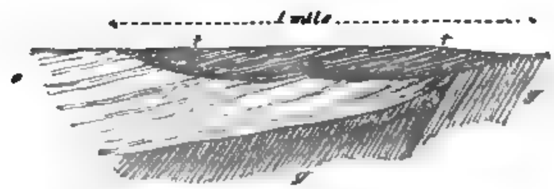
Explanation.

It appeared, however, finally, that the inclination of the Trichinopoly beds to the Northward, although very regular at an angle of from 10° to 3°, (the angle diminishing Northward,) is due to original deposition, and continues very nearly up to their Northern boundary, where the Ootatoor beds have almost the same dip. The Trichinopoly beds, for about half a mile from their Southern boundary, are sufficiently characteristic, although unfossiliferous, being pale grey sands, with large calcareous concretions, and sometimes conglomerates containing clay-nodules from the Ootatoor beds. Beyond this they assume the form of fine sandy silts, and these continue up to the point where, in a little nullah, I found them resting on the Ootatoor beds, which exactly resembled them

lithologically, except that in the latter were intercalated thin plates of Gypsum which were absent in the former. This explanation once clearly established, was of much importance, as it proved how unreliable is the most regular and persistent apparent stratification in these beds, and gave me a clue which proved of much service in elucidating similar anomalies in the mass of the group to the Eastward. The section will be rendered more clear by the accompanying diagram, which represents an imaginary section across the Trichinopoly group, a little to the West of Paroovalapoor.

Importance of the indication thereby afforded.

FIG. 12. SKETCH SECTION OF THE TRICHINOPOLY GROUP.



g. Gneiss; *o*. Ootatoor beds; *t*. Trichinopoly beds.

Crossing the nullah to the East of Paroovalapoor, the Trichinopoly beds spread out in all directions. To the South and East they fill a bay-shaped depression in the gneiss, (4 miles across) and the same distance in depth; the beds resting on gneiss on the Western boundary and on the coral-limestone of Cullygoody to the Eastward, while their Southern extremity is concealed beneath the alluvial deposits of the Cauvery valley, which lap round the extremity of the Thutchuncoorchy granite ridge.

Beds East of Paroovalapoor.

The beds exposed between Paroovalapoor and Seeroovoyalore are sands and sandy shales, with conglomerate, omewhat irregularly stratified, but with a general low dip to the North-east, or away from the gneiss. South of this village little is seen of the lowest beds, owing to the increasing thickness of the superficial alluvium: the village of Thapaye stands a mile to the Eastward, on a bed of granitic gravel, and both to the North and South of it are accumulations of quartz, granitic, and gneiss pebbles, irregularly intercalated in the bedded rocks. To the East and South-east again follows a great mass of fine argillaceous shale, sometimes gypseous, and sometimes full of kunkur, and closely resembling the mass of the Ootatoor beds. Bands of a calcareous conglomerate and blue limestone are occasionally intercalated with these, but fossils are scarce. Almost the only species met with is a *Natica*, closely resembling the *Natica Pagoda* of the Valudayur group. All these deposits dip at low angles, and on the whole to the North-east, as far as the Palambaddy nullah; beyond which the dip is in the opposite direction, and generally low.

Beds around Thapaye.

The mass of the beds with an Easterly dip is much greater than that with a dip in an opposite direction, and in some places the Easterly dip continues to within a short distance of the Eastern boundary, thus repeating on a larger scale the phenomena exhibited by the beds North-west of Paroovalapoor. Irregularities of bedding, accompanied by sudden changes of mineral character, are frequently met with in this part of the group, and I cannot doubt that the inclination of the beds is due to original drifting of the sediment, that from the Westward predominating in amount.

Prevalent Easterly dip of bedding.

Character of Eastern out-crop.

The bottom beds along the Eastern out-crop of the group are chiefly limestones and shales, and rest on the coral-reef ridges lapping round their extremities, and dipping away from them at angles of 20° and 30°, but this high dip only obtains in the bottom beds, and rarely extends more than a few yards. They are rarely fossiliferous, but a few characteristic species are met with. Near the patch of coral-limestone, a mile to the South-east of Veraicoopay, I found some Acteonellas, apparently of the same species as those of the Ootatoor beds at Kolokaunuttom, but associated with *Chemnitzia undosa*, and other characteristic Trichinopoly forms. This was the only spot at which I met with this genus in the Trichinopoly group.

Shingle deposit.

Just North of this spot and on the boundary of the group is a great accumulation of shingle and small boulders, apparently the remains of some ancient beach. I could not determine satisfactorily that it dipped beneath or passed into the gypseous shales, which represent the Trichinopoly group to the West of it, but to the North it appeared to pass into some white and ferruginous sands, which in some places, and notably to the South-west of Malarasure, rest with local unconformity on these gypseous shales.

Beds of doubtful age.

We are here upon the confines of the Arrialoor group, and were it not that throughout this area the irregularities of the bedding are such, that no local unconformities, such as the above, can be treated as of any importance, I should be strongly disposed to regard the beach and the associated sands as marking the base of this group, the more so that near Malarasure the sands spread out and overlap the gypseous shales and pass Northward, with many irregularities, into beds which, at Shutambaudy and Kannanore, contain characteristic Arrialoor fossils. But, on the other hand, similar sands, chiefly of granitic origin, are common in the Trichinopoly beds around, and wherever such occur, they almost invariably present a local unconformity.

Obscurity of boundary between Trichinopoly and Arrialoor groups.

All attempts to fix a stratigraphical boundary between the sands in question and the mass of the Trichinopoly group failed, and such fossils as I met with between Moulvoy and Malarasure were of species common to the two groups, so that the precise limit of the Arrialoor group in this neighbourhood, and the age of the beach deposit, still remain somewhat doubtful. I may here mention, that further North, where the Arrialoor boundary is clear and distinct, it is marked only by the first appearance of its peculiar fossils, or at most by a slight change in the mineral character of the beds. Local unconformity of bedding is nowhere met with at its base, except perhaps at Veraghoor, though the fact of its overlapping the Trichinopoly beds at both extremities of the district, taken in connection with the Palæontological evidence, sufficiently proves its unconformity on the large scale and its distinctness as a group.

Beds South of Moulvoy.

Crossing the narrow strip of plant-beds already described, the Trichinopoly beds consist of irregular alternations of shales with granitic sands, and occasionally with conglomerate, the Eastward dip greatly predominating. Fossils, including most of the characteristic species of the group, are met with at a few localities, and these are chiefly Gasteropoda and Bivalves. Ammonites here first appear, but are extremely rare.

Beds of Western out-crop. North of Paroovalapoor.

Returning for a moment to the Western out-crop of the group between Paroovalapoor and Alundanapuram, we meet with similar irregularities to those already described. A fine mass of shingle, chiefly granitic in its materials, and including many pebbles 5 or 6 inches in diameter, occurs at the base

of the group, about half way between the two above-mentioned places, and conglomeratic limestones full of pebbles of gneiss, granite, quartz, and the yellow marls of the Ootatoor group, are frequently intercalated in the lower beds. The succeeding beds are fine ochreous shales and silts, with occasional bands of limestone, and irregular masses of loose sand exhibiting frequent irregularities of bedding, especially wherever the sands rest on beds of finer texture. In such cases as that exhibited in Plate III., (a nullah section about a mile to the South-east of Alundanapuram,) it would seem that the occurrence of these masses of sand marks a sudden change in the direction of a marine current, which at the first burst swept away a portion of the sediment bank previously formed; drifted a quantity of coarse material over the eroded surface, and that then, as it became more equable and gentle in its flow, finer sediments were successively deposited, and a new bank similar to the former gradually formed, the laminæ only inclined in a different direction. The dip of these sediment layers is sometimes considerable, and I have once or twice observed it as high as 25°. As in the case of the Ootatoor beds the layers are frequently very thin, and as regular as in the most tranquilly formed horizontal deposits.

Irregular bedding.

On the whole, the dip of the higher beds to within a mile of Alundanapuram is to the East and North-east. Beyond this it gradually becomes more conformable to the general strike of the formation, and about E. S. E. Meanwhile the irregularities of bedding become less frequent, and North of Garoodamungalum the bedding conforms regularly to a general N. E.—S. W. strike. Fossils are not very common to the South of Alundanapuram, and the few met with in limestone bands are chiefly Gasteropoda and Bivalves.

Changes in the character of formation about Alundanapuram.

The nullah North of Alundanapuram exposes a very good section of the lower part of the group, including the limestone bands, which commence at Alundanapuram and form the prominent ridge between that place and Garoodamungalum, frequently referred to as one of the best fossiliferous sites in the group. At the base is a thick mass of fine brown sand, which is, however, not well seen here, but is exposed in a little nullah about half a mile further to the North. Some few calcareous nodules occur in these beds, but their fossil contents consist of little else than a species of Oyster and a small smooth Pecten, allied to *P. orbicularis*, both in considerable numbers. Also a small Spondylus, which is one of the commonest fossils of the group, and is apparently identical with a species very common in the Ootatoor beds at Odium.

Alundanapuram Section.

The limestone, which succeeds, consists of several distinct bands, each 6 or 8 feet in thickness, and separated by partings of unfossiliferous shales and white sand, the tail of a thick mass of sand and pebbles which occurs to the East of Alundanapuram. The limestone well known as "Trichinopoly marble" is a blue fine grained rock, in places crowded with fossils, which are not, however, equally distributed throughout, but as is seen in the case of the smaller shells, arranged in lines of drifting, and very unequally accumulated, so that large masses of the rock exhibit no fossils, while others are more than half composed of shells, most of them of a moderate size. The shells are beautifully preserved, the fine polish of the Naticas and Cythereas, and the delicate sculpturing of the Murices, Fusi, and Volutes being unsurpassed by the best preserved specimens of recent shells, and in some cases traces even of the original coloring are still distinguishable. The number of species is very great, and includes Gasteropods and Conchifera in almost equal numbers. Among the most abundant and characteristic of the former are *Strombus contortus*, Sow., two or three species of

Garoodamungalum limestone (shell marble).

Fossils of limestone.

Fusus, *Murex*, and *Pyrula* as yet unnamed: *Voluta Trichinopolitensis*, Forbes, and another allied species*; *Chemnitzia undosa*, Sow., *Turritella monilifera*,† Forbes, and *T. Sowerbii*, Forbes; *Natica suturalis*, Sow., and two or three other species of the same genus; and one or two species of *Rostellaria*. Of the Conchifera the most numerous species are *Arca Trichinopolitensis*, Forbes, *Arca abrupta*, Forbes, and another small species, *Cardium altum*, Sow., *C. Hillanum*, Sow., *C. incomptum*, Sow., and an unnamed species. *Venus Arcotensis*, Forbes, and other smooth species; *Artemis lenticularis*, Forbes; and *Astarte planissima*, Forbes: also a large Mya-like bivalve. A few Ammonites occur also in the limestone, but they are by no means abundant. Fossil wood in the form of water-worn logs, much bored by Seredo, occurs in some of the lower beds in the neighbourhood of the Alundanapuram nullah. One of these measured 7 feet long, and 1 foot in diameter, and a mass of fragments close by, and the impression on the matrix showed that it was originally at least of twice this length. Another log that I measured was not less than 20 feet long. The same bed is full of large pebbles of gneiss and hornblendic schist (from Seraganoor), some of the pebbles measuring as much as 6 or 7 inches and 1 foot in diameter.

In the continuation of one of the limestone beds to the East of Alundanapuram, I found some Rissoœ unassociated with any other fossil, except Cytherea, and close by Mr. Foote procured a few Pycnodont-teeth, the only fish remains, with one exception, met with in the Trichinopoly group. In a bed of shale intercalated in the white sands above the Rissoa band, I noticed also some traces of plant remains, among which one of my colleagues discovered what appeared to be a Zamia, but the specimen was in bad condition, and I felt somewhat uncertain of its identity.

Nullah section continued.

To the North of the Alundanapuram nullah, limestone beds are exposed in the broken ground, dipping about 5° to East by South. Some of them are marked extensively with what appear to be fucoid impressions, and others with what are undoubtedly worm tracks crossing and re-crossing each other as nearly to cover the surface of the bed.

Passing up the nullah across the strike of the beds, the latter are seen dipping at angles of not more than 3° or 5° to the East by South and South-east. Masses of fine, brown laminated sand, or argillaceous sands, with shales and occasional limestone bands, succeed, the bedding tolerably persistent and regular, up to the ridge which forms the local watershed between Alundanapuram and Moulvoy, after crossing which we meet with the irregular beds of sand, shale, conglomerate, &c., described in a previous page. Ammonites and Nautili begin to appear in the concretions and shales of these higher beds, and are tolerably abundant in the broken ground to the West of Serdamungalum. At this spot I found *A. Gautama*, Forbes., *A. Mantelli*, or an allied species, and *Nautilus elegans*, D'Orbigny, which is one of the most characteristic species of the Trichinopoly group. Fossil wood is tolerably abundant in the shales, but in small fragments only.

Beds at Serdamungalum.

Sands with silicified wood. Age doubtful.

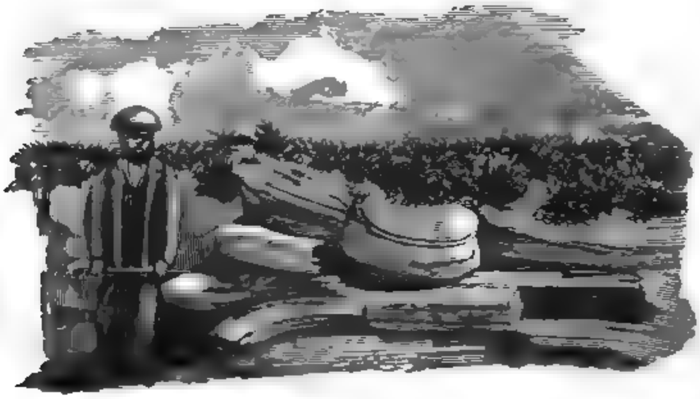
The shales are here succeeded by a mass of white granitic sands and gravels, the upper parts of which are of doubtful age, forming indeed the passage into the Arrialoor group; and in these large logs of silicified wood are imbedded in a prostrate position, and quite untouched by the Teredo, a fragment of one of

* The names of these fossils are quoted from Forbes's Monograph.

† This species occurs also abundantly at the base of the Arrialoor group near Pondicherry. I have not met with it in the Arrialoor beds of Trichinopoly.

them measuring 8½ feet in length, and having been originally, as is evidenced by its impression,

FIG. 18. LOG OF SILICIFIED WOOD NEAR MOULVOY.



of three times that length, is represented in the accompanying figure, imbedded in these semi-consolidated sands, and exhibiting at one end the basis of its roots or branches, which measured altogether 3 feet in diameter, and resembled those of a Dicotyledonous tree. The structure was by no means clear. Another trunk that I measured by pacing was not less than about 60 feet long.

The sands frequently exhibit an internal false-bedded structure in great perfection; the layers having on the whole a predominant dip to the Eastward. These granitic sands and gravels with silicified wood extend about a mile to the North of Serdamungalum, where their lower beds are intercalated with shales and limestone beds of undoubted Trichinopoly age, as evidenced by numerous fossils, such as *Nautilus elegans*, D'Orb., *A. Tamulicus*,* n. s., *Strombus* (allied to but distinct from *S. contortus*, Forbes), *Fusus excavatus*,* n. s., *Chemnitzia undosa*, *Pyrula*, &c., all characteristic species, *A. Pinna* is very abundant here, also a large species of *Opis*, one of *Cyprina* and several species common to the Trichinopoly and Arrialoor groups.

Fossil beds North of Serdamungalum.

The lower beds of the group, between Garoodamungalum and Annapaudy, exhibit much the same character as between the former place and Alundanapuram, and the fossil contents are very similar. *Ammonites* and *Nautili* become abundant in the neighbourhood of Annapaudy, and in the ravines around, and specially to the East of the village, fine specimens of *A. Gautama*, Forbes, *A Tamulicus*, n. s.,* *A. Rhotomagensis ?* and some other species are found in large nodules in the shales, many of the specimens measuring between 1 and 2 feet in diameter. Nautili of two species are also common with Spondylus, Ostrea, Pecten [5-costatus ?], Inoceramus, Pholadomya, and Cerithium, and fragments of fossil wood, in all cases bored by the Teredo. The univalves and bivalves characteristic of the limestone South of Garoodamungalum are here chiefly confined to the bottom beds; where they are, however, not very abundant, many of the limestone bands being unfossiliferous or containing only a few scattered specimens of *Chemnitzia undosa*. These fossils re-appear to some extent in the highest beds close to the boundary of the Arrialoor group.

Lower beds North of Garoodamungalum.

* M.S.S. sp.

The little ravine to the East of Annapaudy which yielded the large Ammonites above-mentioned, exhibits an excellent section of about a mile in length. The beds are fine grey and brown sands and sandy shales, with bands of concretions, occasionally united into almost continuous beds of limestone; the whole dipping very regularly at angles of from 6° to 10° to the Eastward, with slight variations to the North and South of East. Where the little ravine joins the larger nullah, one of the limestone beds is exposed very full of fossils, among which, *Turritella Sowerbii*, Forbes, and a small *Trigonia* are most abundant. I found here the patatal plate of a *Ptychodus* closely resembling that of a species common in the white chalk of England. The higher beds between the large nullah and the Arrialoor out-crop are very similar to the above; fossils being tolerably abundant, and including many of the Garoodamungalum species, with others, such as *Cypræa*, *Opis*, &c., which do not occur lower down, but which pass up into the Arrialoor group.

Section East of Annapaudy.

Returning to the lower beds at Kolokaunuttom; on the camping ground to the West and South of this village three bands of conglomerate limestone crop out prominently in parallel ridges, marking the bottom of the group. The included pebbles are chiefly of gneiss, and their fossil contents consist of *Cardium Hillanum*, a *Pholadomya*, *Astarte planissima*, *Natica*, *Phasianella ?* and fossil wood.

Lower beds, Kolokaunuttom.

Again, in a large well on the North side of the village, a very good section of these lower beds is exposed, exhibiting a succession of fossiliferous sandy shales, with calcareous bands and nodules, dipping 8° to the S. S. E. For some distance to the North of this but little is seen,

FIG. 15. UNCONFORMITY OF TRICHINOPOLY AND OOTATOOR GROUPS, NEAR ILPAGOODY.

beyond the occasional out-crop of a band of limestone, which is either unfossiliferous or contains a few Chemnitzias and fragments of fossil wood, the former characterising the bed as of Trichinopoly age, and distinguishing it from the similar and parallel bands of limestone which here occur in the upper part of the Ootatoor group. On the brow of the ridge between Kolokaunuttom and Shutanure, fossils re-appear in greater abundance, in the limestone, a conspicuous band of which marks the base of the group (Fig. 15) as far as the broken ground represented in the figure. Here its face is fully exposed; and it is seen to twist round almost at a right angle, and rest on the denuded edges of the Ootatoor beds (*see* Fig 15). The local denudation of the latter beds at this spot, previous to the deposition of the Trichinopoly group, is noticeable, when contrasted with their general conformity in strike, and frequently in dip also, elsewhere on the line of junction. As may be seen in the figure, the Ootatoor beds have been so denuded as to leave a steep bank upon which the Trichinopoly beds rest, at an angle of from 20° to 30°; a dip, however, which does not obtain except in the lowest beds. A few yards off the beds are nearly horizontal. The phenomena of this unconformity bear so much resemblance to those of a fault, that were it not for the thorough exposure of the beds in the broken ground, and the absence of any signs of disturbance in the Ootatoor beds, I should have been inclined to attribute them to this cause, but as it is, there can be no doubt whatever of the real state of things. It seems as if a breach had been made in the bank of the Ootatoor deposits at this point, and that in the gap so formed, and which is about 1 mile in width, Trichinopoly beds had been subsequently quietly deposited. These beds are sands and sandy shales of the usual character, and contain many of the characteristic fossils of the group. At one spot South-east of Shutanure Mr. C. Oldham found almost the entire mass of the rock made up of Rhynchonellas and a small species of Terebratula. He met with a similar rock also, some miles further North, in the neighbourhood of Andoor.

Unconformity of groups. Ilpagoody.

Rhynchonella and Terebratula bed.

To the North of Pelamasey the Trichinopoly beds are very uniform in character, and such points as are of interest may be recounted in a few words. Near the base of the group bands of shell limestone, closely resembling that of Garoodamungalum in mineral character and fossil contents, and bands of large calcareous concretions, alternate with sandy shales, and form a conspicuous ridge between Audanoret and Coonum. The out-crop of one of these latter bands is seen close to the village of Audanore. About 100 feet of shale and sand occur below, and these contain few or no fossils.

Bottom beds—Pelamasey.

One of the best sections of these bottom beds is seen in the upper part of the nullah between Permalpolliam and Moonglepaudy. At a point about North by East of Permalpolliam the bottom of the Trichinopoly Group is intersected by the nullah. There is no great unconformity between the two groups, but the bottom bed of the Trichinopolies, an irregular band of sandstone, rest on the eroded surface of the Ootatoors, with the intervention of a thin ferruginous deposit. The lowest beds are, lithologically, almost undistinguishable from the Ootatoor beds, being in part ochreous shales with gypsum, and some calcareous bands, which dip about 8° to the E. S. E. Higher up the nullah, where the limestone bands cross it, the dip rapidly increases to 15°; but this is quite local, and both to the North and South of the nullah, at the distance of a quarter of a mile, the dip of the limestone does not exceed 4°. To the North of the nullah some of the beds are highly conglomeratic,

Junction of groups—Permalpolliam.

and fossil wood is abundant; some of the imbedded trunks measuring not less than 3 feet in diameter. Corals also are abundant in the conglomerate to the exclusion of more fragile fossils, which only occur in the finer arenaceous varieties of the limestone.

Coralliferous conglomerate.

The limestone ridge is very conspicuous as far as Coonum, but beyond this place little is seen of it up to the nullah at Andoor, the surface being thickly covered with regur, which also entirely conceals all the higher beds of the group as far South as Kurribiem. Between this latter place and Permalpolliam they are tolerably well seen, consisting of parallel bands of coarse arenaceous and gritty limestone, alternating with brown sandy shales, and dipping at angles of 5° and 6° to the Eastward. Near Kurribiem I found in some of the highest beds, in conjunction with Ammonites characteristic of the group, a species which in external ornamentation closely resembles *A. bisulcatus*, and others of the Liassic Arietes section of Ammonites. Further examination is, however, requisite to determine its affinities.

Lower beds—Coonum to Andoor.

Higher beds between Permalpolliam and Kurribiem.

In the nullah to the North of Andoor the Trichinopoly beds are again exposed, much diminished in breadth. A band of conglomeratic limestone full of *Chemnitzia undosa*, *Volutas*, *Naticas*, and some of the larger univalves marks the base of the group, and is succeeded by shales, in which are occasionally imbedded gigantic specimens of *Ammonites Gautama*, and other smaller species, and two species of Nautili. One of the first-mentioned specimens, now in the Geological Museum, wanting the greater part of the body whorl, which was too decayed to be extracted, measures 3 feet 6 inches in diameter, the outer whorl being nearly a foot in thickness. When perfect this monster must have measured not less than 5 feet across. Portions of the shell still adhering to it are a quarter of an inch in thickness.

Andoor section.

Large Ammonites.

These beds dip on an average about 8° E. by S. They continue to a point about half a mile East of Veraghoor, where the bottom beds of the Arrialoor group, characterised by their peculiar fossils, cross the nullah. Several bands of limestone are intercalated in the upper beds, showing a concretionary structure, combined with the finely laminated structure of deposition which evidences drifting of the detritus, and the small entire and broken shells which are enclosed, resembling the Garoodamungalum limestone. A small free coiled annelid, with a straight extremity, is very characteristic of the Trichinopoly beds in this neighbourhood, and its presence affords a ready means of distinguishing them from those of other groups when other characteristic fossils are wanting.

Limestones of upper beds.

In the nullah to the East of Poothoor some of the higher beds of the Trichinopoly group are seen dipping about 12° to the E. S. E; but the regur which here covers the surface of the country, to the depth frequently of 20 feet, conceals the underlying rocks, except occasionally in the banks of some few nullahs, and even in them the sections are few and bad. Still further to the North an occasional glimpse of rocks resembling Trichinopoly beds is obtained in the upper part of some of the nullahs draining the East slope of the Purawoy ridge, but the only fossil characteristic of the group that I met within these beds was a keeled Ammonite, which I found in a small nullah

Beds East of Poothoor.

Northern termination of group not ascertainable.

about a mile to the South-east of Vapoor. I could not ascertain at what point the Trichinopoly beds finally disappear, but in a little section to the East of Olapaudy, described at page 95, (Fig. 10, ante,) the Arrialoor beds characterised by several peculiar fossils are seen resting on those of the Ootatoor group, the Trichinopoly beds having been overlapped in the interval.

Deductions from the foregoing.

Disturbance and elevation of Thutchuncoorchy Granitic ridge.

WE have seen in a foregoing chapter that at the close of the Ootatoor period a disturbance, chiefly affecting the Granitic band of Thutchuncoorchy, elevated that region with its overlying deposit, and thus, during the succeeding Trichinopoly period, the coast line, which, in Ootatoor times, conformed approximately to the outline of the hilly region, was diverted to the Eastward, enclosing a bay-shaped depression, in which were subsequently deposited the beds of the Trichinopoly group.

Elevation of Ootatoor group *en masse*, and subsequent denudation.

It is probable that in addition to the Thutchuncoorchy ridge, a large part of the Ootatoor beds to the North, or on the downthrow side of the line of disturbance, were, prior to the formation of the Trichinopoly group, also elevated to such an extent as exposed them to considerable denudation. That such was the case is indicated both by the striking unconformity of the two groups at Ilpagoody (page 119) and Seraganoor, and also by the strong presumptive evidence, that the Trichinopoly group was at one time continuous over the present surface of the Ootatoor beds between Tripatoor or Seraganoor and Garoodamungalum. Now I have endeavored to show that the present dip of the Ootatoor group to the Eastward is mainly, if not wholly, due to its mode of deposition on the edge of a sub-marine bank. The surface of the Ootatoors as now existing, is formed as we have seen of the out-crop of these inclined beds, and is therefore a surface of denudation, and the position of the outliers of the Trichinopoly group is such, that we can scarcely conceive that that part of the Ootatoor group lying between those outliers and the main formation, can have undergone any great amount

of denudation since the commencement of the Trichinopoly epoch. The Trichinopoly beds have indeed been denuded, but supposing that they were originally continuous across, and that there has been no great change in the *relative* levels of the country since the deposition of the Trichinopoly beds, the present surface of the Ootatoor beds can be but little lower than that on which these Trichinopolies were deposited.

Apparent general conformity of group.

But, on the other hand, we have seen that the strike of the Trichinopoly beds, and in many cases their dip also, very closely coincide with that of the Ootatoor beds on which they rest; a fact which would at first sight seem to militate against the above conclusion. This is however, with few exceptions only, the case in that part of the formation which stretches North-east and South-west, and is, I consider, to be sufficiently explained by the general direction of the Trichinopoly coast line to the North of the dislocation, having so far coincided with that of the Ootatoor coast line, that the banks of sediment which constitute respectively the Ootatoor and Trichinopoly groups, are also, for the most part, nearly parallel.

Bedding determined by irregular deposition.

Along the Southern boundary, or in other words, at the head of the bay formed by the Thutchuncoorchy ridge, we have seen that the Trichinopoly deposits are very irregular, and consist of materials derived in great part from the rocks of that ridge. The general dip of the beds is to the East or North-east, and the opposite dip of the deposits on the Eastern ridge of the basin prevails to a very short distance only from the boundary of the formation. This fact, even in the absence of other evidence, would induce the suspicion that the inclination of the bedding is that of original deposition; and is not due to subsequent disturbance, a view, the correctness of which is proved almost to demonstration, by such clear instances on a smaller scale at that of the Paroovalapoor outlier, and by the frequent local unconformities and irregular dips of

the whole Southern part of the formation. The banks of shingle near Thapaye and Jewalapoor indicate the existence of beaches at these points, during the early part of the Trichinopoly epoch, which were subsequently buried beneath sands and gravels, as submergence progressed. That to the North of Cullygoody is probably of later date, and may have belonged either to the close of the Trichinopoly period, or the commencement of that of the Arrialoor group.

Shingle deposits.

The Trichinopoly group is, as we have seen, restricted in extent. There is no reason to believe that subsidence ever progressed to such a point as to submerge the Thutchuncoorchy ridge during its formation, for while there is no evidence of any denudation of the Trichinopoly beds previous to the commencement of the Arrialoor period, the deposits of the latter overlap the former at the extremity of this ridge, and contain pebbles of the gneiss and granite of which it is formed. At their Northern extremity the Trichinopoly beds are obscured by superficial deposits, so that we cannot ascertain the features of the Arrialoor overlap in that direction, but from the strike of the bedding, it is very clear that the Trichinopoly deposits diminish rapidly from South to North, and it is very probable that the bank of sediment never extended in any great thickness much beyond the actual Northern extremity of the Trichinopoly out-crop.

Land area of Trichinopoly period.

The inclination of the bedding in the Northern and more regularly deposited part of the group is lower than that of the Ootatoor group, averaging 6°, and nowhere exceeding 15°, except when the lowest beds rest on denuded slopes of the Ootatoor beds, as near Shutanure. In some of the local unconformities of the irregular deposits to the South I have observed dips as high as 25°.

With respect to the distribution of the fossils, it is noticeable that but very few occur in the irregularly deposited part of the group, large areas being totally unfossiliferous. Not a single specimen of Ammonite has been met with in this part of

Distribution of fossils.

the group, as far North as Moulvoy, although shells of the genus are tolerably abundant in the neighbourhood of Garoodamungalum and Annapaudy, where the beds become more regular. In the limestone at the base of the group, the fossils are very numerous, as a rule, and very various, numbers of different species being mixed indiscriminately in the rock. In the higher beds this is less frequently the case, and the fossiliferous bands are usually characterized by the exclusive occurrence or the predominance of some one or two species, especially *Spondylus* and *Trigonia*.

Age of Trichinopoly Group.

As regards the age of the Trichinopoly Group, little more can be said than that it is considerably newer than the Ootatoor Group, and is decidedly Upper Cretaceous.* So far as the fossils have been examined, they tend to confirm Professor E. Forbes's opinion, that it is about of the age of the Upper Greensand, and its relations to the Arrialoor group, (the fauna of which reminds one in many respects of that of the White Chalk,) also support this view: but until the whole fauna has been examined, it would be premature to offer any decided opinion on this matter.

CHAPTER VIII.—*Arrialoor Group, in Trichinopoly District.*

Extent of Group.

THE extent of the Arrialoor group in Trichinopoly alone considerably exceeds that of both the groups previously treated of; and unlike them it extends beyond the limits of the district, and occupies a large area to the North of the Vellaur, which will be described in a succeeding chapter. In Trichinopoly it occupies a broad strip of country in the Arrialoor and Wodiarpolliam sub-divisions, extending from the banks of the Vellaur nearly to those of the Coleroon,

* In the foregoing pages, where the terms Upper and Lower Cretaceous are used, I draw the line of separation at the base of the Gault of Europe. By Middle Cretaceous I do not intend to refer to any distinct sub-division, but only to position in the Cretaceous series.

and comprising an area of about 200 square miles. In the vicinity of the latter river it is concealed by superficial deposits, (regur and alluvium,) and at Tanjore, 12 miles distant, where the older rocks re-appear to the South of the Cauvery delta, these consist of the Cuddalore sandstones, a group of doubtful age, but newer than the Cretaceous rocks, upon which they rest in Trichinopoly and South Arcot. It is probable that the Arrialoor beds may be concealed beneath these beds at, or to the East of Tanjore, judging from the strike of the boundary North of the river; and if so, they may possibly re-appear at some point to the South which has not yet been surveyed. This, however, is at present mere surmise.

Much of the Arrialoor beds are concealed beneath cotton soil, and sections are even rarer in these beds than in those of the older groups.

Lithological features.

They consist, in great part, of white unfossiliferous sands, and green argillaceous sands with casts of small fossils in the unconsolidated matrix. Bands of calcareous grit and nodular calcareous shales are frequent in the lower beds, and these abound in fossils, and similar shales re-appear in some of the higher beds.

Zonal sub-divisions.

Indeed although there are no very definite boundaries between the sub-divisions of the group, there are in the Arrialoor group of Trichinopoly three tolerably well defined zones, the lower and uppermost of which are fossiliferous and characterised by distinct faunas, while the middle zone, consisting chiefly of white and grey sands, is almost without fossils. These zones pass into each other in South Arcot, but it will be convenient to observe the distinction in describing the more extensive deposits of Trichinopoly.

Conglomerates are comparatively of rare occurrence in the group, and, except near its Southern boundary, we do not meet with those frequent irregularities of bedding which characterize a large part of the Trichinopoly group. The dip of the beds is generally very low, the highest (6°) only prevails in the lower beds of the group, where they rest on Trichinopoly beds. Elsewhere dips of 2° and 3° are prevalent, the

inclination being towards the North-East. At its Northern and Southern extremities the group rests on gneiss, overlapping the older groups on which it rests in the interval. Its thickness is not easily ascertainable,

Thickness doubtful.

but not only its low angle of dip, but also the fact that the gneiss bottom protrudes through the beds at more than one spot, more than a mile from the boundary of the group, warrant the inference that its thickness is nowhere very great, probably not exceeding 1,000 feet.

Source of materials.

The constituents of the Arrialoor beds were derived in part from the granitic band of Thutchuncoorchy, in part from the gneiss, and a few pebbles of yellow marl in the conglomerate-beds, show that the older (probably the Ootatoor beds) were also undergoing denudation to some extent at the time of its formation. As compared with the lower groups, the bedding of the Arrialoor group is very uniform, and the beds thick and homogeneous.

Fauna.

The fauna of the Arrialoor group is one of great interest. That of the lower beds includes many of the commonest forms of the Trichinopoly fauna, and a few of these range through a large part of the group, but they are associated with a large proportion of new and peculiar forms, and, as a whole, the fauna offers many striking points of contrast to those of the lower groups.

Resemblance to that of 'White Chalk.'

It is essentially *Upper Cretaceous*, and in many points reminds one strongly of that of the white chalk of Europe, especially in the abundance of *Bryozoa*, *Echinida*, *Brachiopoda* and small *Corals*, and the occurrence of such forms as *Crania* and *Marsupites*, both of which are absent in the lower groups. Ammonites are common in the lower beds, chiefly of peculiar species, but including a few, such as *A. sugata*, Forbes, and *A. Mantelli*, which have passed up from the lower groups. *Nautili* are numerous both in species and individuals ; all of them peculiar to the group as regards our Indian formation, but including some European forms,

notably *N. Bouchardianus, N. Clementinus* and *N. Danicus*. The occurrence of this last (in the highest beds only in Trichinopoly,) is remarkable, not only in the mere fact of its occurrence, but also in its association with an *Ovulum*, and a fauna having as much of a Tertiary as of a Cretaceous aspect, and peculiar to the beds in question. It is true that at Valudayur, near Pondicherry, *N. Danicus* occurs in the lowest beds of the group, as also do the *Ovulum, N Bouchardianus* and *Turritella monilifera*, with other forms occurring in the lower part of the Arrialoor group, but from the way in which all the Arrialoor beds thin out to the North I think it probable that for long periods little or no sediment was deposited *on this* part of our area, so that a thickness of a few feet at this spot may represent as many hundreds of feet in area of more abundant deposition in Trichinopoly, and thus fossils *may*, in the absence of sections, appear to be mingled together, which, in Trichinopoly, occur in distinct and widely separated bands.

Intermixture of fossils at Pondicherry.

Hamites, Baculites and possibly *Turrilites* re-appear in the lower part of the Arrialoor group, having been nearly or entirely absent from the Trichinopoly deposits, and *Radiolites* of more than one species are extremely abundant at a particular zone; Squaloid teeth *(Lamna, &c.,)* are found in some of the lower beds, as also in the same formation at Pondicherry, but the most remarkable and interesting occurrence is that of remains of the *Megalosaurus*, a reptile which in Europe has not been found to range above the Wealden formation. These remains, which I shall describe more fully further on, consisted of bones, (in so bad a state of preservation, however, as to have little recognizable form,) and one tooth, upon the discovery of which the identification of the reptile therefore rests.

Fossil wood is not uncommon in the fossiliferous beds of the Arrialoor group, but is less abundant than in the Trichinopoly beds. Its nature I have not ascertained.

The following generic list of fossils drawn up as in previous cases from our field lists, will convey a general idea of the character of the fauna *:—

VERTEBRATA.

REPTILIA.	PISCES.
Megalosaurus.	*Squaloid teeth.*
	Lamna.
	Corax.
	Otodus.
	Oxyrhina.
	Odontaspis.

ARTICULATA.

Crustacean claws, &c.

Annelids (*Serpula, Spirorbis, &c.*)

MOLLUSCA.

CEPHALOPODA.	BRACHIOPODA.
*Nautilus.**	*Terebratula.**
*Ammonites.**	*Rhynchonella.*
Baculites.	*Crania.*
Turrilites.	
Hamites.	
GASTEROPODA.	CONCHIFERA.
Rostellaria.	*Ostrea.**
Pyrula.	*Pecten.**
Fusus.	*Lima.*
*Voluta.**	*Spondylus.**
Ovulum.	*Plicatula.*
*Natica.**	*Vulsella.*
Pyramidella.	*Perna.*
Chemnitzia.	*Inoceramus.**

* In the above list I have only noted with an asterisk the genera most abundant in individuals, data being insufficient to enable me to note specific abundance also.

Cerithium.
Nerinæa.
Turritella.
Scalaria.
Solarium.
Nerita.
Turbo.
Trochus.
Rotella ?
Pleurotomaria.
Cinulia.
Acteonella.
Bulla.
Cylichna ? or a new genus.

Pinna.
Mytilus.
Modiola.
Arca. *
Pectunculus.
Trigonia.
Radiolites. *
Cardium. *
Lucina.
Corbis.
Cyprina.
Astarte.
Crassatella.
Opis.
Cardita.
Cytherea.
Corbula.
Pholadomya.

BRYOZOA. *

RADIATA.

Echinodermata.
Spatangus * *or Micraster.*
Nucleolites. *
Catopygus.
Cidaris ?
Echinus ?
Marsupites.
Crinoid stems.

Polypiaria.
Fungia.
Turbinolia, &c.

PROTOZOA.

Foraminifera.

PLANTÆ.

Fossil wood, sp. ?

Details of the Geological Structure.

Southern extremity.

The Southernmost point at which I have met with beds of the Arrialoor group is between the villages of Kullure and Koloture, about 2 miles from the bank of the Coleroon, due North of Tanjore. They here crop out from beneath the alluvium, or rather the thick cotton soil deposit, which extends along the North bank of the river; and are laid bare in several little nullahs and patches of broken ground. The beds are yellow sandy shales, with occasional calcareous bands, the whole but slightly consolidated, and dipping about 4° to the Eastward, and therefore away from the gneiss, which is seen *in situ* in the village of Kullure. Similar beds are met with at several points between Kullure and Arringaul and near Shathamungalum; they yield several of the characteristic fossils of the group, *viz.*, *Ammonites* of two or three species; *Nautilus Bouchardianus*, D'Orbigny, *Nautilus rota*, n. s., *Voluta*, *Ostrea tegulanea*, Forbes, *Inoceramus*, *Trigonia*, *Pecten 5-costatus*, *Cardium Hillanum*, *Arca Trichinopolitensis?* *Opis*, *Pholadomya*, *Terebratula biplicata?* and *T. arabilis*, Forbes, and a *Spatangus*.

Fossils.

Sands at Kullagoody.

The greater part of the country to the East and North-east of Koloture is thickly covered with red soil, and nothing is seen of the underlying rocks for several miles; but at Kullagoody, a mile to the North-east of Arringaul, a loose pale-grey and yellow sand, unfossiliferous, and such as characterizes a large part of the beds to the Northward, is seen in some irrigation wells in tolerably good sections.

Lower beds. Mulloor gneiss boss.

From Shathamungalum past Keelapulure to the Trigonometrical station of Shillagoody little is seen of the Cretaceous rocks, but on the Northern slope of the high ground, (which is covered with small outliers of Cuddalore sandstones,) the beds are well exposed in the nullahs which carry off its drainage. In one of these, about a mile to the South of Mulloor village, a fine mass of gneiss, penetrated by granite, protrudes in the middle of the Cretaceous rocks, which dip away from it on all sides. It extends about a quarter of a mile up the nullah, in which the Cretaceous rocks beyond are also well exposed. The lowest beds of these are calcareous and somewhat conglomeratic, frequently including small boulders, but there are no regular accumulations of pebbles, such as characterize some of the lower beds of the Trichinopoly group. Fossils are abundant, especially *Terebratula*, and *Echinida* of the genera *Spatangus?* and *Nucleolites*.

White sands and ferruginous nodules.

The fossiliferous beds are succeeded by a considerable thickness of white sand, and grey and ochreous sandy shales, the former exhibiting but little bedded structure, except that due to their mode of accumulation by currents, of which kind of irregular bedding they offer some very beautiful examples. Ferruginous concretions and thin tile-like partings are common in these beds, and have apparently at some former period been collected for smelting by the natives, to judge from the piles of slags met with in the neighbourhood. Excellent sections of these sands, with their capping of Cuddalore sandstones, are seen in the nullah that runs past Paupanchary into the Murdayaur, and also in the upper part of that which passes to the South of Mulloor. They are for the most part unfossiliferous.

Fossiliferous beds of Shillagoody.

The nullahs in the neighbourhood of Shillagoody and Karapaudy expose beds similar to those near Mulloor, *viz.*, calcareous and sandy shales, abounding in fossils of a great variety of species. Fine specimens of *Nautilus Bouchardianus* are especially abundant.

Area of irregular bedding.

It is noticeable that a line drawn from the point where the boundary of the Arrialoor beds turns to the South-west near Shillagoody station, across to Koloture, where the group rests on Trichinopoly beds, marks off an area, (to the South) within which the strike of the bedding by no means conforms to that of the boundary of the group. As far South as Shutambaudy and Kannanore, ther ocks have indeed a tolerably regular bedded structure, the dip of which, (except where close to the boundary,) is at a low angle to the North-east, but beyond this all becomes confusion, and so far as can be ascertained, there is no definite line of demarcation between the beds of the Arrialoor group and those of the Trichinopoly group described at page 115. To the North-west and South of Moulvoy a perfect chaos of irregular bedding, as inextricable as that which characterizes the Southernmost deposits of the Trichinopoly group, is exhibited in the steep banks of the nullahs, and although a few fossils are met with in the irregular calcareous bands here and there intercalated in the sands, which constitute the main portion of these deposits, they are, so far as I have been able to identify them, of such species (Arca Trichinopolitensis, e. g.) as are common to the two groups. To the East of Moulvoy some greenish sands are exposed in one or two wells, which, to judge from their mineral character, are probably of Arrialoor age, and in a calcareous band, a short distance to the East of Shutumbaudy, I found a specimen of *N. formosus*, n. s., one of the characteristic Nautili of the Arria'oor group.

Apparent passage.

Inoceramus Grits.

From Shillagoody station to Shutumbaudy, the lower beds of the group are marked by a series of parallel bands of calcareous grit, intercalated in sandy shale, some of these bands are full of fragments of *Inoceramus*, a peculiarity which is very characteristic of the Arrialoor beds ; and where other indications are wanting will frequently serve to distinguish them from similar grits in the Trichinopoly group. These beds are quarried to some extent for building purposes by the natives.

Beds North of Shutumbaudy.

On the slope of the high ground to the North of Shutumbaudy, the beds are well exposed in some deep nullahs. They consist of soft shales with calcareous bands, and contain a few fossils of Arrialoor age. They dip at a low angle to the N. N. E or N. by E.

Fossiliferous conglomerate. Kannanore.

Crossing to the western boundary of the group, we meet with a bed containing characteristic Arrialoor fossils in the village of Kannanore, near the tank bund, and also in a little nullah to the South-east of the village. In some places this bed is conglomeratic, crowded with large pebbles of yellow quartz evidently derived from the granite to the South. The fossils are chiefly of species common to the Trichinopoly and Arrialoor groups, *Trigonia, Venus, Pecten 5-costatus, Cardium Hillanum*, &c., but an *Ammonite*, (undescribed, sp.) a *Natica*, a *Perna*, and a few other fossils, are of species found only in Arrialoor beds. This conglomerate bed rests on some white false-bedded sands, (exposed in some small nullahs to the West of the tank), which extend for some distance to the South of the village, and are identical in character with those which, near Moulvoy, contain fossilized tree trunks (page 118), and those which, with granitic gravels and other irregular deposits, to North of Serdamungalum underlie the fossiliferous beds described at page 117. Moreover on following the shallow sections of these sands, exposed in small nullahs to the South of Kannanore, they seemed to pass gradually into shales with intercalated bands of calcareous grit, containing a few doubtful fossils, while a few hundred yards to the Westward similar and parallel bands

contained fossils of undoubted Trichinopoly age. We might hence infer these sands to be of Trichinopoly age, and might assume the Kannanore conglomerate to be at the base of the Arrialoor groups, but on the other hand, sands of precisely similar character are intercalated with fossiliferous beds of Arrialoor age near Shutambaudy and again to the East of Koloture, and as they include pebble conglomerates similar to that in question, but unfossiliferous, there is equal reason to believe that this fossiliferous conglomerate, which is quite local and does not extend 50 yards to the South of the village, is merely a lenticular patch deposited under similar conditions to the sands themselves. So far as can be ascertained, the whole of the beds, apart from frequent false-bedding, are conformable, dipping at angles of 2° to 4° to the Eastward. About half a mile to the South of the village, the dip changes to N. E. N or N. N. E., but that of the Trichinopoly beds changes likewise and a N. E. dip prevails through the beds in the neighbourhood of Moulvoy and Serdamungalum. On the whole therefore I infer that the white sands of Kannanore, which are co-extensive with those to the North of Moulvoy, form the Northern extreme of the irregular deposits, which extend from Malarasure, and which can be classed neither with the Trichinopoly nor Arrialoor groups. Connected to some extent with both these groups, they appear to mark an intervening period of shifting deposits, offering conditions eminently unfavorable to the preservation of fossils. This period was possibly of long duration, so that a considerable change had taken place in the character of the local fauna before the recurrence of that period of regular deposition, which coincides with the commencement of Arrialoor time.

Apparent passage.

For some distance to the North of Kannanore nothing is seen of the lower Arrialoor beds, and near Koloture we first find the base of the group tolerably well defined. About 150 yards beyond the Eastern end of the tank bund of the village, a ridge of blocks of conglomerate, full of fragments of *Inoceramus* and pebbles of the Ootatoor (?) beds, is seen coursing along the hill side in a N. N. E. direction. This bed belongs to the Arrialoor group, as is proved by its yielding a number of very characteristic fossils; 50 yards to the West of it is another similar band of calcareous conglomerate, full of pebbles of quartz and felspar, and fossils characteristic of the Trichinopoly groups, and therefore at this point either the conglomerate first mentioned is the bottom bed of the Arrialoor group, or the base of the group must be somewhere between the two beds. Unfortunately there are no sections in which the precise relation of the two formations can be ascertained On the high ground to the East of Koloture, however, the beds which immediately succeed these lowest, are exposed to a considerable extent. They consist of white sands with shaly intercalations, in which are found a number of characteristic fossils. Among the common species are *Nautilus Bouchardianus*, D'Orb., two or three *Ammonites* of the Rhotomagensis and Lævigati sections; *Inoceramus* and *Cyprina* with *Nautilus Trichinopolitensis*, n. s., and *Nautilus rota*, n.s., *Rostellaria*, *Turritella*, *Scalaria*, and several other species in smaller numbers. The most interesting fossil I found at this spot was a tolerably perfect specimen of a *Marsupite*, almost the only one met with. The general dip of the beds is East 6°.

Bottom beds at Koloture.

White sands and fossiliferous shales. Koloture.

The white sands extend for some distance to the North, but are rarely exposed, owing to the character of the country, which is low and flat, and evenly covered with black soil. They are met with at Goodaloor and again to the South-East of Coothoor, and 2 miles to the East of that village, I found similar beds in a well just beyond the outlier of the Cuddalore sandstones

which caps the high ground to the West of Arrialoor. Again similar beds, associated with greyish and greenish sands, and soft ochreous shales, constitute the lower part of the group to the East of Kurribiem, beyond which nothing is visible for some miles. They are generally unfossiliferous and have little perceptible dip. Where ascertainable it does not exceed 3° or 4°.

Extent of white sands Northward.

In the bottom beds of the group are intercalated calcareous bands, similar to those of the Trichinopoly beds immediately below them. Indeed, it is frequently almost impossible to determine the exact limits of the groups; as their beds are locally conformable, and only fossiliferous in a few places. Here and there the point can be determined by the discovery of some characteristic form of fossil, but in general the boundary given in the map can only be considered as approximately accurate.

Difficulty of separating groups.

I have already mentioned, that in the Arrialoor, as in the lower groups, the general strike of the bedding is more Northerly than the boundary of the group, or in other words, the deposits in the Southern part of the area cover a wider extent of country than an equivalent series in the North of the district.* Before therefore proceeding to describe the lower beds of the groups in the Northern part of the district, it will be desirable, following the order I have hitherto observed, to return to the beds in the neighbourhood of Arrialoor, and to trace them Northwards as part of the lower fossiliferous zone to their disappearance beneath the alluvium of the Vellaur.

The broad band of cotton soil and alluvium that extends up the valley of the Murdayaur, to within a mile of Arrialoor, entirely conceals the underlying Cretaceous rocks. North of this alluvium, a narrow belt of Cretaceous rocks is exposed, between the former and the capping of Cuddalore sandstones, which overlies the Cretaceous rocks in the Eastern part of the district, but these rocks, which consist chiefly of white sands, belong rather to the middle unfossiliferous zone, the description of which may be deferred for the present.

Beds S. E. of Arrialoor.

The rocks around Arrialoor contain a fauna very similar to that of the lower beds, except that the Trichinopoly species, which form a considerable proportion of the latter, have somewhat diminished in number. The beds are well seen at the Kalingula, or waste channel, of the large tank to the West of the native town. At this spot they are nearly horizontal, dipping only 2° to the Eastward, they consist of calcareous sandstone and grit, somewhat conglomeratic, and abounding in fossils; among which Nautili of four or five species are very abundant, *Pecten 5-costatus*, *Arca Trichinopolitensis*, *Arca abrupta* and *Cardium Hillanum* also occur together with species of *Baculites*, *Natica*, *Turritella*, *Pleurotomaria*, *Spondylus*, *Plicatula*, *Ostrea*, *Vulsella?* *Pectunculus*,

Fossiliferous beds of Arrialoor.

* I am not in a position to assert that the beds in the South are thicker than in the North, because I have no reason to believe that any calculation based upon the amount of their dip would give reliable results. I have endeavoured to prove in the case of the Ootatoor and Trichinopoly groups that there is strong reason to believe their bedded structure due to banking of the deposits rather than to equable horizontal deposition, and we have also seen in the Southern part of the Arrialoor Group, at all events there are evidences of similar irregularities of accumulations. I think it very probable that the greater out-crop of the Arrialoor group is owing to the sedimentary accumulations having been more abundant here, and as in the case of the Ootatoor Group deposited over a larger area, the later deposits being continually swept to the outer edge of the area.

Inoceramus, *Opis*, *Cytherea*, *Pholadomya*, *Echinida*, and fossil wood in great abundance. These beds rest on some sandy shales with calcareous nodules, which are exposed to a depth of 20 feet in a well about a hundred yards to the Westward. Similar beds alternating with bands of calcareous sandstone, seem to form the bulk of the formation for about a mile to the Westward, and are seen round the village of Nochycolum, and in some other places in the vicinity. They pass downwards into the white sands,* previously described, and with which they are seen alternating in nullah on the East of the Cuddalore sandstone outlier of Husain Nagrom.

East of Arrialoor.

The beds to the East of Arrialoor consist chiefly of soft sandy shales with calcareous bands, the latter generally full of fragments of Inocerami. They are seen occasionally in the banks of small nullahs, but no good sections are exposed, and the country, as a rule, is much obscured by regur. Mr. Chas. Oldham obtained the following fossils from some of these beds to the South-east of Arrialoor;

Terebratula arabilis? Forbes, abundant.	*Inoceramus.*
Ostrea tegulanea, Forbes.	*Lima.*
Gryphæa stomatoidea, Forbes.	*Echinida*, chiefly *Nucleolites;* very abundant.
Spondylus.	
Pecten.	

Beds of the above character extend as far Eastward as the villages of Peddipolliam and Maunahadoor, and they are probably continuous with the highly fossiliferous beds near Ootacoil, to the North of Arrialoor.

For 3 or 4 miles to the North of Arrialoor but little rock is met with *in situ*, but on the ridges along which the road runs from Arrialoor towards Ootacoil, a large species of *Gryphæa* is found in great numbers scattered over the surface.

North of Arrialoor.

In several nullahs draining the Western slope of the sandstone-capped ridge North-east of Parchary, Cretaceous rocks are seen in the form of soft, yellow and grey shales with calcareous concretions, but generally unfossiliferous. Again on the high ground North of Mungalum similar beds are seen, with laminated sandy clays, and bands of coarse white sand, semi-consolidated and highly false-bedded. The clays contain numerous casts of small univalves and bivalves, which appear to have been disseminated through them in great numbers. The casts are sharp, and the species easily recognizable, but owing to the softness of the matrix are not easily preservable. Similar clays with fossil casts occur in great thickness in many parts of the Arrialoor group and appear to be characteristic of the formation. They extend for about 2½ miles to the East, alternating in thick banks with sands, shales, and calcareous bands: the latter abounding in fossils.

Clays with casts of small fossils.

Fossiliferous beds of Ootacoil.

In the nullah to the East of Ootacoil, (*see* map) these latter beds are well exposed, affording one of the richest fossil localities in the formation. *Nautilus Bouchardianus* and *N. Clementinus* are very abundant here, with a *Baculite*, and several species of *Ammonites:* of the smaller fossils the most abundant are:—species of *Cerithium*, *Trochus*, *Rotella?*, *Mytilus*, and *Radiolites* of two species, the last exceedingly numerous, and in good preservation, but generally wanting the inner layer of the shell. Some specimens, however, appeared to show casts of the teeth, or at least of those on the upper valve. Other genera here met with are *Fusus*,

* These sands, which are intercalated in the lower fossiliferous zone, should not be confounded with those which form the central unfossiliferous zone.

Voluta, Natica, Chemnitzia, Nerita, Acteonella, Ostrea, Lima, Pinna, Lucina, Astarte, Cytherea, Nucleolites and *Spatangus* with *Serpula,* and some fossil wood.

A considerable thickness of red sandy clay, alternating with coarse white sandy shales, succeeds the fossil band, and passes into the irregular deposits of sands and sandy clay, (containing the remains of the Megalosaurus,) which forms the Northern continuation of the beds alluded to at page 134, and the consideration of which I have deferred.

I have now brought the description of the whole of the lower fossiliferous beds up to the point at which I left that of the lowest beds at page 134, and to these therefore we may now return. For about 2 miles to the North of Coothoor, and about 4 miles to the North of Kurribiem, (where I left the lower beds), the cotton soil conceals the Cretaceous rocks. In the nullah that runs past Veraghoor, and which cuts through all these three groups, we again meet with the lowest beds of that under consideration, and obtain a tolerable section of rather more than a mile in length.

North of Kurribiem and Coothoor.

The bottom bed of the group crosses the bed of the nullah about half a mile East of Veraghoor. It is a soft, (decomposed,) grey sandstone, containing many of the most characteristic fossils of the formation, and dipping about 3° to the East by South. Among the fossils occurring in this bed are a *Crania,* nearly allied to if not identical with *C. Iguabergensis,* and the two small corals, *Fungia filamentosa,* Forbes ? (*Cycloseris filamentosa,* Milne Edwards et Haime,) and *Turbinolia Arcotensis,* Forbes, (*Trochosimilia Arcotensis,* Milne Edwards et Haime,) both characteristic of the Arrialoor beds of Pondicherry.

Bottom bed. Veraghoor.

This fossil bed is succeeded by a considerable thickness of shales, having a somewhat higher dip, about 6°, and these are followed by some coarse white and tinted sands, or friable sandstones, which are exposed in the large nullah South-west of Vaitagoody ; but the section is by no means continuous. Some fossiliferous bands are intercalated with them, and one which is exposed in the same nullah, afforded some fossils similar to those of the bottom bed. On the ridge to the East of Vaitagoody, similar sandstones are exposed in one or two places in wells. They are sometimes fine in grain, and shaly, but unfossiliferous. About a mile farther to the Eastward calcareous bands, (probably the continuation of those at Ootacoil,) are exposed in a nullah to the East of Kaudoor ; and at some other points further up the same nullah, the direction of which nearly coincides with their strike : also near the village of Chockanadapuram ; at all of which localities some characteristic fossils are met with, chiefly the species of *Nucleolites* and *Spatangus. Inoceramus,* both entire and in a fragmentary condition, abounds wherever other fossils are met with, and *Bryozoa,* both attached and free forms, are very common. *Terebratula,* probably *T. arabilis.,* Forbes, *Gryphæa stomatoidea,* Forbes, and *Ostrea tegulanea,* Forbes, are all common and characteristic of the group.

Succeeding beds.

Beds of Kaudoor and Chockanadapuram.

To the North of Kaudoor, the beds I have been describing begin to disappear beneath the thick covering of alluvium and regur, which fill the valley of the Vellaur. The bottom beds indeed are exposed at intervals up to within 3 miles of the river, protected apparently from denudation by the Ootatoor limestone ridge upon which they rest. But the higher beds, consisting, as we have seen, chiefly of unconsolidated sands, and soft friable shales, have been largely denuded, and subsequently covered with regur ; and although they may be seen occasionally in native wells and

Unequal denudation.

similar excavations as far North as Cootoomoor and Thoongapooram, little more can be made out of them than that the succession of beds appears to continue much the same as I have just described. The ridge running up to Cootoomoor is formed by the fossiliferous calcareous bands which we have traced up from the East of Arrialoor; and that terminating at Thoongapooram is formed by the coarse sands, some hard beds of which have probably enabled them to resist denudation better than the soft sandy clays and friable shales which intervene between them and the calcareous bands. It is probable also, that the Kothavassel capping of Cuddalore sandstones extended along the ridge to Thoongapooram, almost till the close of the final denudation, and these beds, cemented by iron and calcareous infiltrations into a tolerably hard rock, have preserved the ridge in question, which is considerably above the average level of the surrounding country.

Bottom beds. Olapaudy.

With regard to the bottom beds, a few words more are necessary. Imperfect sections of these beds are exposed in the nullah to the East of Poothoor, (where, as in the Veraghoor nullah, the bottom bed is seen resting with no apparent unconformity on the Trichinopoly beds); and also in some other small nullahs, which cut across the strike of the beds between Poothoor and Olapaudy. At this latter place the bottom bed of the Arrialoor group is a coarse conglomerate, consisting of blocks of gneiss and Ootatoor limestone, (both of which are *in situ* a few yards from the spot,) imbedded in a soft sandy matrix. Some of the imbedded boulders were as much as 2 feet in diameter, the majority not more than 6 inches to 1 foot, and most of the limestone blocks, even as imbedded, were covered with a polished ferruginous crust, similar to that characteristic of weathered laterite. The cause of this I could not clearly ascertain; the amount of iron in the limestone being (as ascertained by analysis) very small; so that the rock *in situ* shows no tendency to assume a similar appearance: yet the limestone blocks alone exhibited the peculiarity in question. The bed, which is well seen where it crosses the Cootoomoor road, is 3 or 4 feet in thickness, and is followed by brown and grey sandy shales, which are exposed in some broken ground by the side of the road, and abound in fossils of numerous species.

Conglomerate.

Fossils at Olapaudy.

Nautilus Bouchardianus is very abundant, the specimens being many of them of large size: several species of Ammonites, including *A. sugata*, Forbes, a *Hamite*, a *Baculite*, and species of the following genera, were also collected by Mr Chas. Oldham:—

Rostellaria.	*Pecten.*
Fusus.	*Spondylus.*
Voluta.	*Inoceramus.*
Natica.	*Lima.*
Cerithium.	*Arca.*
Turritella.	*Nucula.*
Turbo.	*Opis.*
Pleurotomaria.	*Lucina.*
Terebratula.	*Brissus.*
Rhynchonella.	*Nucleolites ?*
Crania.	*Cidaris.*
Ostrea.	*Marsupites.*
	Serpula.

together with some fragmentary remains of Crustacea, some Shark's teeth, and fossil wood. As is usually the case in the Arrialoor group, the fossils are very beautifully preserved, the shells of the Nautili and Ammonites remaining perfect, while, the matrix being soft, they are easily extracted without injury.

Northern termination of lower zone.

On the summit of the ridge to the North of this place a small nullah that runs down to Vylapaudy exposes a good deal of the shales near the base of the group with their included calcareous concretions. Here also many of the fossils above enumerated are to be found with but little search. These beds may be followed down the nullah to Vylapaudy, where they finally disappear beneath the alluvium.

Middle or unfossiliferous zone.

Having thus described the whole of the lower fossiliferous zone of the Arrialoor group, we will return to the Southern extremity of its out-crop, and follow up, in a similar manner, the broad band of nearly unfossiliferous sands which succeeds, and separates the former beds from the interesting fossil zone of Sainthoray and Ninnyoor.

Beds East of Murdayaur.

I have already (page 134.) mentioned that to the North of the Murdayaur alluvium or rather of the thick regur deposit occupying the hollow through which that stream flows, a narrow band of Cretaceous rocks is exposed between the regur and the Cuddalore sandstones. There is some difficulty at this point in distinguishing the two formations, inasmuch as their lithological characters are for the most part very similar, and no fossils are found in either group which might aid in determining the relative age of the beds. From near the banks of the Coleroon to Kondamungalum, beds of coarse grit, strong-

Grit escarpment—Kondamungalum.

ly stained with iron, (a form of rock highly characteristic of the lower beds of the Cuddalore sandstones,) form a small bluff, (evidently an old marine escarpment,) along the margin of the alluvial plain. At Kondamungalum it turns off to the Northward, becoming much less abrupt as it retreats and finally merging into a gentle slope, which still preserves, however, something of the character of an irregular coast line, and follows for 4 miles in a North-west direction, the summit of the ridge which separates the Murdayaur from a small parallel nullah farther to the North. On the Southern or Murdayaur-ward slope of the ridge, the Cretaceous rocks are frequently exposed, the

Character of Cretaceous beds.

upper beds being chiefly white or tinted shaly sandstones, with large concretions of chert; the lower beds, fine sands or soft shale similar to those of the fossiliferous band below. The former beds are well seen in the upper part of the valley, the drainage of which feeds the Keelanuttom tank. In some places they are very coarse in texture, consisting of a grit more or less stained with ferruginous infiltrations from above, and they are then quite undistinguishable from the grits of the Cuddalore group. Indeed I

Resemblance to Cuddalore sandstones.

should strongly doubt whether these beds be really Cretaceous rocks were it not for their resemblance to beds of less doubtful position (and in the general direction of their strike) further North, and also that they are sometimes intercalated with the soft ochreous shales, so characteristic of the Cretaceous ormation generally in the Trichinopoly district. As it is, I have not been able satisfactorily to determine the limits of the two groups in this neighbourhood, owing to the high ground being evenly covered with red soil, and the line given in the map can only be taken as the best approximation to the truth that my local knowledge of the beds, and the data of the locality would admit of my making.

The shales and fine sands which underlie the sandstones above mentioned, are seen in a well at Ambapuram, and in one or two shallow nullahs near the border of the alluvial plain. They are quite unfossiliferous.

The highest beds of the fossiliferous zone described at page 135, pass in a N. N. W. direction past Reddipolliam, and a little to the North-east of Maunahudoor, whence they continue Northward to the East of Ootacoil. A short distance above (*i. e.* to the East of) these beds, some unconsolidated white sands are seen in a small nullah North-east of Reddipolliam, and again in a well at Pereya Nagalore, and these are followed by a considerable thickness of green shaly clay, which is well exposed in the broken ground at the head of the nullah to the East of the latter village. So far as any dip can be observed in these beds, it appears to be at a very low angle to the North-east, but for the most part they are almost horizontal. Still further East, in the broken ground South of Thaloor, these clays pass again into white sands, in which are found a few cherty concretions, 1 or 2 feet in diameter. These concretions are far more numerous in some beds of argillaceous sand exposed in the small nullah that crosses the Wodiarpolliam road 2 miles East of Thaloor. Some of them are as much as 4 feet in diameter, the chert is grey and opaque, in some parts porous in structure, and enclosing soft ferruginous nodules of concentric structure, which have evidently resisted the silicifying infiltration. These concretions appear to be characteristic of a particular zone. I have already (page 138) described their occurrence near Keelanuttom, 5 miles to the South, and Messrs. King and Foote met with them, (containing recognizable fossils,) imbedded in the conglomeratic grits at Vullam fort, to the South of the Cauvery. In this latter case they were probably derived from Arrialoor beds, denuded during the formation of the grits, but if so, it is improbable, from their large size, that they could have been transported from any great distance.

White sands of Reddipolliam, Pereya Nagalore, &c.

Chert concretions at Thaloor.

At Vullam.

For 3 or 4 miles to the North of Thaloor, the country is too thickly covered with regur to allow of much rock being seen, the chief exception being that in the nullah that passes by Keelymungalum some nodular calcareous shales are exposed, but containing no fossils.

Passing on towards the watershed between the Vellaur and Coleroon rivers, a tolerably consecutive view of the beds, under consideration, is obtained in the various small nullahs at the head of the drainage system. These beds, here exposed, overlie the highly fossiliferous shales of Ootacoil, described at page 135.

White sands, &c., at Cullmoad.

The red clays, with casts of small fossils, which I have mentioned, (loc. cit.) as succeeding the fossil band of Ootacoil, are well exposed in the West branch of the nullah which passes Cullmoad, and in the East branch of the same nullah for about half a mile above the village. At this point the nullah is crossed by the out-crop of a bed of sandstone, which rests on the clay, and dips about 4° to the North-east; and this is succeeded by a mass of white sands and grey sandy clays, which are extensively exposed in the system of gullies above, which cut deeply into these soft beds. Imbedded in the deposits, large bones are numerous, but so saturated with water and so very friable, that it is impossible, even with the greatest care, to extract them in anything like a recognizable condition.* Fortunately for their determination I found a single tooth

Megalosaurian remains.

* The most perfect bone extracted has somewhat the form of a scapula, but is much splintered. It measures 3 feet 3 inches in length, and 1 foot 6 inches across at its broadest end.

of a Megalosaurus which, although not found attached to any bone, affords at least strong presumptive evidence that the bones in question are the remains of the same animal.

All the bones that I observed were isolated, and had possibly dropped off one by one, as the carcass to which they were attached gradually decayed. There seemed, however, no reason to believe that they had been derived from any previously formed sedimentary rocks. The beds were not conglomeratic, and the fine mud which filled the cavities in the bones, was of the same nature as the clay which was intercalated in thin bands in the ossiferous sands. There seems no reason to doubt that the *Megalosaurus* which in Europe is not known to range higher than the Wealden Group, lived on, in the Indian area, to a period coeval with the extinction of *Ammonites* and *Belemnites*, and with the first dawn of a Tertiary fauna.*

Bones of contemporaneous date.

The bone band is quite local. It may be traced for about a mile in the direction of Coothoor, but is not much exposed beyond Cullmoad. To the North it speedily disappears beneath 'regur,' and is not again met with.

Extent of bone bed.

A considerable series of deposits similar to the above extends to the Eastward, and is exposed in the upper part of the nullah to the East of Cudoor; they are very gypsiferous, and all springs emerging from them are highly saline and bitter. They dip at from 2° to 4° between E. N. E., and N. E., and are quite unfossiliferous.

Succeeding beds.

To the North of the watershed, and up to its very crest, a thick deposit of regur conceals the greater part of the beds I am describing, and only their upper portion, having an out-crop of from 1 to 2 miles broad, is occasionally exposed on the Eastern border of this deposit. A mere enumeration of some of the localities at which these are seen will be sufficient, as they afford but little additional knowledge of this part of the group.

Unfossiliferous zone in North of district.

White sands are seen to the East of Mootoopolliam, on the borders of the village tank. Again in, and around the village of Sainthoray, green sandy clay and shales are exposed in some wells, and also in the little nullah that runs down from Ninnyoor. Immediately to the North of the latter village, a soft white sandstone appears in a small nullah, in the upper part of which the higher fossiliferous beds are exposed, and similar sandstones, resting on greenish sandy clays and shales, are seen in the broken ground to the North of the village. These sandstones are distinctly false-bedded, with a flaggy structure, and only half consolidated, crushing readily under a slight blow.

About a mile North-west of Yellakudumboor, similar sandstones are seen in a little drain cutting through an old tank bund, and between the same village and Chittadiaur the flaggy white sandstones, frequently more or less stained by ferruginous infiltrations from the surface, are indicated by numerous fragments scattered over the surface of the ground. This is the farthest point North at which I have noticed these beds. They disappear finally beneath the alluvium, and to the East and North-east the only Cretaceous rocks exposed are those of the higher fossiliferous zone, to which I now proceed.

* It will be seen in the sequel that no Ammonites are met with in the higher fossiliferous beds, and the appearance of *Nautilus Danicus*, two or three species of *Ovulum* and a number of others almost entirely different from those of the lower beds forces the conviction that we have here deposits of a period not earlier than the Mæstricht beds of Western Europe.

Upper fossiliferous zone.

It will have been observed in the foregoing descriptions that of this upper belt of fossiliferous rocks, nothing is seen anywhere in the neighbourhood of the Coleroon, and indeed up to the watershed of the district, the Cuddalore group rests upon the unfossiliferous band I have described above. In the nullah near Authicoodicaud, (a village near the boundary of the Cuddalore beds, 3 miles North of the Arrialoor and Wodiarpolliam road,) we first meet with the fossiliferous beds of the upper zone. The beds are grey and ochreous shales, sometimes calcareous, and containing a species of oyster in considerable abundance. Two miles farther North similar calcareous shales are met with in a little nullah to the East of Sainthoray, about half way between that place and Vellapencoorchy. The country is here covered with red soil and a low jungle, and the beds are only seen in the nullah which cuts into them to a depth of 5 or 6 feet. At this place fossils are tolerably abundant, and they comprise a number of species not previously noticed. The most striking are *Nautilus Danicus*, Schloth., and a large thick bivalve, probably a *Crassatella*, fragments of which are abundantly strewn around. There are also several smaller shells, *Naticæ Arcæ*, *Turritellæ*, &c., most or all of them apparently distinct from those of the lower zone; and an *Ovulum*.

Fossiliferous bed at Sainthoray.

At Ninnyoor.

Again a mile further North, in the upper part of the nullah that runs past Ninnyoor, the same band is exposed, and more extensively, while the fossils are far more numerous and various than at either of the localities previously noticed. *Nautilus Dunicus* and the *Crassatella* here also predominate, imbedded in a loose calcareous shale. No Ammonites are associated with them, and the characteristic Mesozoic genera, *Inoceramus*, *Radiolites*, *Trigonia*, *Pleurotomaria* and *Opis*, all of which are common in the lower zone, and some of them particularly abundant, are equally wanting in the Ninnyoor beds. *Nerinæa* indeed is the only characteristic Mesozoic molluscan genus which links the fauna with that of Cretaceous times, while the general aspect of the fauna reminds us more of that of Nummulitic or at least Tertiary times, in the association of *Voluta*, *Fusus*, *Ovulum*, *Turritella*, *Natica*, *Trochus*, *Solarium*, *Chemnitzia*, *Pyramidella*, *Modiola*, *Cardium*, *Cardita*, *Crassatella*, *Corbula*, *Corbis*, *Lucina*, *Venus* and *Cytherea*. There is much resemblance between some of the species and those of the Rajamundry beds, the fossils of which have been described by the Reverend S. Hislop, and one species of Turritella appears to be identical with *T. prælonga* of that formation. An Echinid occurs, but distinct generically (*Catopygus*) from those of the lower beds, and some corals, the affinities of which I have not determined.

Resemblance of fossils to those of Rajamundry.

Age of upper zone.

It will be seen from the above, that the Tertiary aspect of the fossils of the Ninnyoor bed is more due to the absence of characteristic Cretaceous forms than to the presence of those which we have been accustomed to regard as peculiar to Tertiary deposits; but the latter are not entirely wanting. Regarding these facts alone, it is difficult to avoid the conclusion, that in these beds we have deposits at least as recent as the Mæstricht and Faxoe beds of Western Europe. But, on the other hand, we shall see in our review of the Pondicherry area, that we there find *Nautilus Danicus*, *Ovulum* and *Oliva*, apparently associated with *Nautilus Bouchardianus*, an *Ammonite*, a *Hamite*, *Ostrea tegulanea*, *Ostrea stomatoidea*, and a number of other fossils of the lower zone, and above all with *Turritella monilifera*, a fossil which in Trichinopoly does not range

even into the Arrialoor group. It may, indeed, be a question whether the bed at Pondicherry in which these fossils occur be the precise stratigraphical representative of the bed at Ninnyoor, or whether, (the Arrialoor beds having greatly thinned out towards the North,) it may not represent a portion of the lower zone, in which the more recent forms above enumerated appeared locally at an earlier epoch than in Trichinopoly. Again, it is possible that in the thickness of a few feet, we may have in South Arcot the representatives of a great part of the Arrialoor formation of Trichinopoly, and thus the association of the fossils in question be rather apparent than real. Some circumstances, which will appear in the sequel, seem to confirm this as the most probable view.

Meantime, to return to local details. The Ninnyoor calcareous beds are met with again about a mile further to the North, in the nullah to the East of the village of Yellakudumboor. They are here very similar in mineral character to those above described, but are poor in fossils, and I only met with one or two ill preserved specimens of *N. Danicus*, and the large *Crassatella*: beyond this, nothing is seen of any fossiliferous beds for a considerable distance, and it is probable that the beds in question disappear beneath the alluvium. Beds of similar mineral character occur, however, higher up in the series, and are seen near the village of Thoolaur, 4 miles North-east of Ninnyoor, thence they strike to the East of Thombarapoondy, and may be traced by their debris on the surface from a point a little to the North of the latter place, to the bank of the Cautoday nullah, opposite Mooticoorchy, where they are laid bare in the bed of the nullah. No fossils are observable in them up to this point, but here the bed is full of specimens of *Nautilus Danicus*, most of them of gigantic size. The bed is only exposed in the nullah and in the bank above, and beyond it is concealed by alluvium. Finally it re-appears in the bed of the Vellaur about a mile to the North of Aulathor, forming a broad stony barrier across the river, where the water is low : the bank above is formed by a little cliff of Cuddalore sandstones. At this spot a few fossils occur; among them, *N. Danicus*, some *Turritella*, a *Rostellaria*, and a few bivalves.

Beds at Yellaukdumboor.

Higher beds at Thoolaur.

Fossil bed at Mooticoorchy.

In the Vellaur.

Between this band and that of Ninnyoor, the Cretaceous rocks, so far as they can be seen, appear to consist of sandy clays and soft shales, with a band of flints exactly resembling in the mineral character, and the nature of the enclosed organisms, the chalk flints of Europe. I did not see this in place ,but to the west of Coorchycolum the flints appear at the surface, and are collected by the natives for the same purpose as similar flints were in Europe previous to the invention of lucifer matches. They are much shattered, and appear to form a continuous band rather than isolated nodules. They are full of foraminifera, and occasionally contain small corals and other fossils of large size. At only one other place did I meet with similar flints, *viz.*, about a mile to the South-east of Sainthoray, (6 miles South of Coorchycolum,) and they were there of precisely the same character as at Coorchycolum. It is possible that the band is continuous between the two places, although not even ; for the whole of this country is so covered with red soil, that only at very rare intervals is the underlying rock rendered visible.

Band of Flints.

With this I conclude the description of the Arrialoor beds of Trichinopoly; the formation, as already mentioned, re-appears in South Arcot

and is there of some extent, and it will be convenient, therefore, to defer any summary of the facts above detailed till I have described the remaining portion of the formation further to the North.

PART II. § 2. VERDACHELLUM AND PONDICHERRY AREAS.

CHAPTER IX.—*Arrialoor Group in Verdachellum Area.*

Relation of Cretaceous rocks and Cuddalore sandstones.—We have seen in the preceding chapter that, as we pass from Ootatoor to the Northern limits of the Trichinopoly district, the different groups of fossiliferous rocks successively overlap those beneath them, until, at the confines of the Vellaur alluvium, (which covers up the whole series for a distance of from 5 to 16 miles,) the Arrialoor or highest group rests immediately on the gneiss, and occupies an area of not less than 8 miles in width, measured across the strike, to where it is covered up by the Cuddalore sandstones. These latter rocks occupy the country to the East, and the superficial Geology of the stratified rocks, so complicated in the South of the district, is here, at its Northern limits, simplified to the superposition of these two groups, beneath which the older members of the series are concealed.

North of Trichinopoly district.

If we now cross the broad alluvial plain of the Vellaur and Mani Mûkta to the high ground in the neighbourhood of Verdachellum, we find the same two groups of rocks emerging from beneath the alluvium, and stretching away to the North, until they again disappear beneath the alluvial deposits of the Guddalum and Puniar. Owing, however, to the gradual overlapping of the Cuddalore sandstones, the area occupied by the Cretaceous rocks in the neighbourhood of Verdachellum, is much diminished in width, and it is further decreased by two large outliers of the former formations, which at two points entirely overlap the latter and rest immediately upon the gneiss.

Near Verdachellum.

The Cuddalore sandstones here, as elsewhere, occupy high jungly ground, with a thick covering of deep-red sand, which conceals them everywhere except at their scarped boundary. That the deposits at a former period extended across the whole area now occupied by the stratified rocks, and that the

Exposed by denudation.

Cretaceous rocks have been exposed by subsequent denudation, is at once apparent on glancing at the map,* and it is probably, in consequence of their lower level, that, as in Trichinopoly, the Cretaceous rocks are in great part covered with regur, which conceals the greater part of their out-crop.

Much concealed by regur.

They now occupy a strip of country from 2 to 3 miles across, extending from the bank of the Mani Mûkta to that of the Guddalum, but they are only exposed at one or two places, the principal of which is Messrs. Kaye and Cunliffe's original fossil locality in the neighbourhood of Pulliyur or Paroor. Thanks, however, to the reduction of the land rental within the last few years, many wells have been sunk in different parts of the area, for the irrigation of the hitherto waste lands, and these have disclosed the presence of Cretaceous rocks over a large area, where it would otherwise have been difficult to establish the fact of their occurrence. They present themselves for the most part as a soft sand, or a sandy clay, with casts of small fossils, and there appears to be a passage from coarser to finer materials, as we proceed from South to North. The bottom bed is generally calcareous, and sometimes forms a tough arenaceous limestone, at other times it occurs in the form of thin calcareous shales. It is also sometimes conglomeratic, but the pebbles are few and small, and nowhere is there anything like a coarse conglomerate such as occurs at base of the Arrialoor group in the South of Trichinopoly. The beds appear to have been deposited in a tranquil sea, free from shifting currents, and they have undergone little, if any, subsequent disturbance.

Lithological characters.

Fossiliferous beds of Pulliyur.

The beds of arenaceous limestone which, as I have above stated, occur at the base of the group, are well seen in a nullah about a mile to the South of Pulliyur (Paroor), a village 5 miles North-west from Verdachellum. About 12 or 15 feet of a

* That is the corrected map. Owing to some strange blunder a space of about 20 square miles to the North-west of Verdachellum is, in the Atlas Map, only correct in the names of some of the villages being *enumerated*. They are all transposed from 3 to 5 miles from their correct position, and the large stream takes an impossible course over some of the highest ground in the neighbourhood: even the road to Oolunderpet is fully a mile to the West of its proper place.

coarse arenaceous limestone, with thin irregular partings of a dark clay, are seen in the bank of the nullah, and cropping out on the surface of the ground above. The bottom bed contains a few gneiss pebbles, and immediately on it rests a band of calcareous grit, in which a Trigonia, *T. semiculta,* and one or two large species of *Spondylus* and *Pecten 5-costatus* occur in considerable numbers. Resting on this is a bed of similar mineral composition, the fossils of which consist almost exclusively of two species of Pecten *(P. quinquecostatus and P. Verdachellensis)* both in great abundance. A few other species are associated; but on the whole the locality is an unproductive one. The fossils are either species peculiar to the locality, (as *P. Verdachellensis,* which, although so abundant at this place, has not been met with elsewhere,) or they are such as are common to the Arrialoor beds of Trichinopoly and Pondicherry. Among the species noted as from Verdachellum in Professor E. Forbes's Monograph and also in Mr. Kaye's Collection in the Madras Museum, there are many species which belong exclusively and characteristically to beds of the Trichinopoly group, of which I have found no trace in the neighbourhood of Verdachellum. If therefore the reference of these forms to Verdachellum be not erroneous, and due to their accidental admixture in Mr. Kaye's collection, there must be some small outlier of the Trichinopoly beds which I have not succeeded in discovering; but this I think highly improbable. The matrix in which these fossils are imbedded is quite different from that of the Arrialoor beds of Pulliyur, and resembles the Garoodamungalum limestone, a form of rock frequently occurring, as at Garoodamungalum, at the base of the Trichinopoly group.

Bottom bed near Pulliyur.

From the Pulliyur nullah, the out-crop of the limestone is very distinct for about half a mile to the North; it then passes in the thick red soil jungle to the East of Pulliyur, the thorny Acacias of which render any attempt to trace it a matter of no small labor; besides which the thick accumulation of red sand entirely conceals it, except at one or two spots, where the ground is broken by

nullahs. A few traces of it are seen near where it crosses the Verdachellum and Oolunderpet road, at Pulliput, but all the country to the North, as far as Chendamungalum, is so deeply covered with soil, that nothing is seen except in wells, and a few scattered debris that have apparently been imbedded in the soil. It appears, moreover, probable that the limestone band either dies out or breaks up into a mass of loose kunkur-like concretions, or thin calcareous shales, interbedded in the soft white sandy shales, which are seen in a few wells near the boundary. At Chendamungalum, however, the limestones re-appear in the banks of the large square tank of the old fort. The beds are thin and irregularly concretionary, and tinged of a yellow color, probably with the ochreous clay derived from the older bed; their dip is very small, departing but little from the horizontal, and no fossils were discernible: just beyond this the cretaceous beds plunge beneath the alluvium of the Guddalum, and are not again visible to the North-east until we reach (Verdoor) Valudayur.

At Chendamungalum.

At Killanur and Numbakkund a white sand, with a somewhat shaly structure, is seen in some wells not far from the bottom of the Cretaceous rocks. In this soft matrix I found a few casts of small fossils, but the species were not recognizable; they consisted chiefly of small bivalves. A similar sand full of casts of small fossils is seen half a mile to the East of Chendamungalum. Among them I recognized a *Turritella*, a small *Voluta*, a *Nucleolite*, and a few bivalves, *Leda*, *Solecurtus*? and *Cytherea*.

Sand with small fossils.

That the Cretaceous beds are probably very thin over the whole of the Verdachellum area is proved not only by the low dip of the stratification wherever this is visible, but also by the fact that near the Eastern boundary of the Southern Cuddalore sandstone outlier a small patch of gneiss, evidently in place, is met with about half a mile to the North of the village of Periya

Thinness of formation.

Wurrawaddi.* A very small patch only is exposed, and its real extent is not ascertainable, owing to the covering of soil, but it is probably not very large. In a well in the village of Periya Wurrawaddi Cretaceous rocks are exposed, and in the jungle around the little patch of gneiss a good deal of calcareous kunkury shale is scattered about similar to that which characterizes the base of the group at Killanur, and other places on the boundary.

Nucleolite bed.

At Yeramanur, still farther South, a quantity of half-consolidated sand thrown out of a newly dug bowrie, is full of *Nucleolites*, of apparently the same species as that which characterizes the lower fossiliferous zone of the group in Trichinopoly. A few other fossils occur with it, *viz.*: an *Ostrea*, a *Pectunculus*, a Flustra-like *Bryozoon*, and fragments of a large Inoceramus resembling *I. Cuvieri* both in form and size.

Higher beds.

The higher beds are only seen at one or two places, and seem to be a compound of fine sands and shales, containing but few traces of fossils. At Kallakurchi, the debris thrown out of an irrigation well, consists of soft white sandy shale, and at Kalamodee, 3 miles to the Eastward, a fine white sand, with traces of plant remains (apparently grass or reeds), is seen also in the debris of a well. With regard to this last, I am uncertain whether it be really Cretaceous, or from the bottom beds of the Cuddalore sandstones, which undoubtedly occur *in situ* a very short distance beyond. The rock bears most resemblance indeed to that of the Arrialoor deposits; and within a furlong to the North-east another well exposes a grey argillaceous sand not differing greatly in mineral character from the above, but which the included casts of fossils prove to be Cretaceous. The boundary of the Cuddalore group is, however, very irregular, and resemblance in mineral character unsupported by other evidence is an unsafe criterion of identity, as many

* This is not the village of that name, marked on the map, but a village about half way between the former (really Matur) and the village marked as Matur.

beds of the Cuddalore sandstones are undistinguishable lithologically from those of the Arrialoor group.

Between Yualakappam (Kordirakuppam of the map) and Palkollei, a small nullah flowing down from the Eastward, exposes some of the Cretaceous rocks consisting of shales with large calcareous concretions, exhibiting sometimes the zig-zag structure, similar to those of the Ootatoor and Trichinopoly groups previously described. They are quite unfossiliferous; at Yualakuppam a soft laminated sandy clay, equally unfossiliferous, is seen in the debris of a well close to the little outlier of Cuddalore beds on which the village is built. Cretaceous rocks of similar character are also seen in the neighbourhoods of Isarikuppam and Korilaveram, close to the overlap of the Cuddalore beds.

Relations of Arrialoor beds of Verdachellum to those of Trichinopoly.—It is somewhat difficult, owing to the general obscurity of the Arrialoor beds in the Verdachellum area, to correlate them, with any certainty, with those of the same group in Trichinopoly. The area, as a whole, is characterized by the absence of fossils, and only at Pulliyur and Yeramanur do we meet with any distinct representatives of the lower fossiliferous zone. The fine sands with casts of fossils, which occur near the boundary of the group at Killanur and Chendamungalum, remind us of the similar beds in the upper part of the same zone near Coothoor (page 136), and in the same way the unfossiliferous sands and clays which appear to constitute the whole of the beds to the Eastward, may be the continuation of the unfossiliferous zone in Trichinopoly; as indeed the strike of the bedding would indicate; but if such be the case, the mineral characters of the beds have become much changed in the interval,—the deposits being finer and more argillaceous, and exhibiting less irregularity in their mode of accumulation, than is the case with the white sands and sandy shales of the Northern part of the Trichinopoly district. Moreover the deposits have greatly decreased in thickness, or at least the area occupied by their out-crops has become much narrower, (owing to the

decrease of sediment) from South to North. This decrease continues rapidly as we follow the group still farther in the same direction, until at length we find, in the Pondicherry area, no further distinction between the three zones so clearly defined in Trichinopoly, but fossils characteristic of the highest and lowest of these zones, apparently intermingled in the same bed at the very base of the group.

PONDICHERRY AREA.

CHAPTER X.—*Valudayur and Arrialoor Groups.*

Extent of Cretaceous rocks.

THE Pondicherry district is smaller than either of those previously described, but presents some Geological features of special importance. It extends between the alluvial plain of the Ariancoopum and that of the Mercanum, the latter not intersected by any stream of importance, and lying at a low level, so that the greater part of it forms a perennial marsh, but in other respects it much resembles the alluvial plains already described, and is evidently due to the same series of physical causes.

Of Cuddalore Group.

The area occupied by the sedimentary rocks is not more than 10 miles in its greatest length, while in the other direction, *viz.*, from the sea coast inland, it extends from 8 to 12 miles. The whole of this tract was, at a comparatively recent period, occupied by a thin capping of the Cuddalore sandstones, ridges of which still extend along its East and West limits, the former being known as the Red Hills of Pondicherry, while the latter, which has received no special name, may be designated as the Trivicary ridge. In the intermediate space, 5 miles in width, the Cretaceous rocks have been exposed by recent denudation, and their out-crop being but little elevated above the level of the Mercanum alluvium, they are much obscured by the covering of older alluvium or regur, which occupies the whole denuded area, and renders it difficult to ascertain clearly the relations of the underlying rocks.

Obscurity of Cretaceous rocks.

Position of Valudayur.

The village and fort of Valudayur (Verdoor), (the latter an important French outpost during the war of the Carnatic, but long since abandoned to the peaceful dominion of the plough, and existing only as a quadrangle of ruined earthwork, surrounded by a dry ditch,) are situated about 10 miles inland from Pondicherry, and near the border of the alluvial plain of

the Ariancoopum. A good pucka bungalow, very convenient for the Geological visitor, existed here five or six years ago, but being at some distance from any of the main lines of road, it has now been dismantled, and, at the date of my last visit, in the beginning of 1860, was no longer habitable. Valudayur is still, however, an important village, and being surrounded by some magnificent groves, is a convenient place for encampment, from which to visit the fossiliferous localities first brought to notice by Messrs. Kaye and Cunliffe. Being situated near the extremity of the Cretaceous rocks, it is also the most convenient point from which to commence their detailed description.

Fossiliferous beds of Valudayur.

About half a mile to the East of Valudayur, after crossing a deep water channel, excavated by the French Government for the supply of the great Ossatary tank, we meet with a low rocky bank, formed by a yellow calcareous conglomerate full of fossils, as is evidenced by its stony debris abundantly scattered around. The imbedded pebbles are of various sizes, up to 8 or 10 inches in diameter, well rounded, and consisting principally of a compact grey limestone, as is seen when some of the larger of them are broken across; for they are for the most part so much weathered, that they bear more resemblance to the marl nodules of the Ootatoor group of Trichinopoly, than to the original rock from which they are derived, and which crops out near the base of the conglomerate a little way to the North-east. A few pebbles of gneiss and quartz also occur, and the coarse sandy matrix, which constitutes the mass of the bed, consists of the same materials. The fossils are very abundant, and generally well preserved, but can only be extracted in good condition when the matrix is somewhat decomposed.

Arrialoor fossils.

Turritella monilifera, (a species which in Trichinopoly has only been found in the Garoodamungalum limestone, and beds of the same group); and a small unribbed *Arca*, *A. Gamana*, Forbes, are perhaps the most common. *Fungia filamentosa* and *Ostrea stomatoidea*, both

characteristic 'Arrialoor' species, are also very abundant, and *Nerita elegans*, a *Trigonia*, (*T. semiculta ?*) and several other species, many of them yet undescribed, occur in smaller numbers. This bed may be clearly traced for a distance of about half a mile, striking S. S. W., and where it crosses the canal just above the sluice gates, it is seen in section dipping about 2° or 3° to the South-east. At this point it is a concretionary limestone, having lost much of its conglomeratic character and containing few fossils, and those not in a recognizable condition. In one respect it is peculiar, being full of contorted cylindrical casts, about half an inch in thickness, which appear to pierce the stone in every direction, although they only become visible when weathered. The origin of them it is difficult to explain satisfactorily; the most probable supposition is that they are casts of the borings of annelids in hard sand, such as may well have been the original material of the bed. This bed, preserving the same mineral character, may be traced for nearly a mile along the canal, being visible just above the water, when the latter is low, and further indicated by a great quantity of stony debris scattered along the right bank. It then turns abruptly to the Westward, and is lost in the soil in the neighbourhood of Ossatary tank.

Returning to the starting point near Valudayur, and proceeding thence in an opposite direction, we soon lose the out-crop of the bed beneath the cotton soil with which the ground is uniformly covered. The little bank formed by the hard projecting edges of the bed becomes merged in a gentle grassy slope facing to the North, which trends away in the direction of Sydrapet (Sudarampet), and for about a mile little is to be seen but loose fragments of conglomerate scattered over the surface, and a few larger blocks half buried in the soil. Imbedded in, and intermingled with these, I have obtained *Ostrea tegulanea*, *Fungia filamentosa*, and other common "Arrialoor" species, also *Nautilus Danicus* and *N. Bouchardianus*,

both common fossils of the same group. It is, however, to be observed, that these indications of the conglomerate bed are not scattered indiscriminately over the entire slope, for they do not occur below a certain line, beyond which the stony fragments, large and small, have an entirely different character. These latter consist of great nodules or fragments of nodules of a dark-grey compact limestone, never conglomeratic, and most commonly without fossils, but where fossils occur, they are in vast numbers, large and small indiscriminately intermingled, and congregated in nests in the mass of the nodule. The species are, so far as I have been able to compare them, all different from those of the conglomerate bed, and probably, owing to the fineness of the matrix, they are in beautiful preservation, the more fragile specimens being sometimes broken, but never rolled. *Baculites vagina* and *Pholadomya lucerna* are the most conspicuous species, *Baculites teres*, a small sharply-ridged *Hamite*, (*H. tenuisulcatus?* Forbes) *Strombus uncatus*, Forbes, *Solecurtus obscurus*, Forbes, are less common, and with these are a mass of small bivalves and univalves, the species of which I have not determined. It is remarkable that, while in Messrs. Kaye's and Cunliffe's collections obtained from this spot, the Ammonites were among the most numerous and best preserved specimens of the collection, I have not been able to obtain a single good specimen of the genus. Fragments of some of the smaller species, as *A. Rouyanus*, *A. Kayei*, &c., I have indeed seen, but even these rarely, and I can only attribute my ill fortune to my having come into the field after the locality had been searched and researched by many sharp-eyed collectors, of whose visits the rejected fragments scattered about furnish abundant evidence, this is, and must be, the case where no new material is furnished by quarries or other excavations. In so limited an area the first comer will naturally carry off the best prizes. I may notice, however, that

"Valudayur" limestone.

Fossils of.

the majority of the Ammonites that I have seen from Pondicherry are evidently from these or similar limestone nodules, and in only one or two instances have I been able to identify any as certainly from the overlying conglomerate bed.

Character of "Valudayur" beds.

The surface of the ground being grassy, or arable land, at only one or two spots, in little field drains, are these calcareous nodules seen *in situ*, and here they appear to form a band imbedded in soft sandy shale, in which they have been formed by concretionary action. The dip of the stratification cannot be ascertained with certainty, but wherever any bedding is clearly seen in this group of beds, as in some of the bowries (square wells) around Vanoor, it is either horizontal, or dipping 2° or 3° to the South-east, and judging from the strike of the fossiliferous nodule band, it probably coincides with this prevalent structure.

Proofs of two distinct groups.

From what I have above stated, the conclusion at which I arrive respecting the relative ages of the two fossiliferous bands is evident. Although no unconformity of stratification can be detected, partly because the discordance, if existing locally, must be very small, and partly because the evidence bearing upon this point is very obscure, the facts which remain, *viz.*, the distinctness of the fossils in the two rocks, the divergent relations of the two faunas, as established by comparison with those of the Cretaceous series of Trichinopoly; and finally, the occurrence of pebbles of the older rock in a conglomerate of the newer, are quite sufficient to prove that a long period of time must have elapsed between the formation of the limestone nodule bed and the deposition of the conglomerate rock with Arrialoor fossils. This conclusion first deduced from the comparison of the fossils, and the examination of the rocks of this locality, has been fully borne out on extended examination. The conglomerate bed, though not always presenting itself as a conglomerate, but more generally as a hard fossiliferous limestone or

calcareous sandstone, has been traced as far to the North-east as the edge of the Mercanum alluvium, while limestone nodules similar to those of Valudayur have never been found elsewhere then below, *i. e.* to the West of the out-crop of the former bed.

I have described in some detail the country around Valudayur, not only because it possesses a special interest, as the original locality from which the fossils described by Professor Forbes were obtained, but also because it affords a fair example of the Geology of these rocks, as they occur over the whole of the Pondicherry area, and that a detailed account of the locality explains the reason, that the occurrence of two distinct deposits has escaped the notice of previous observers. Nowhere is any section obtainable exposing the two rocksin absolute superposition, and nowhere can their stratigraphical structure be traced with such accuracy as to afford a distinct proof of unconformable bedding.

Valudayur group much obscured by regur.

Of the two groups, it unfortunately happens that the lowest, which in many respects is the most interesting, and that concerning which information is most required, is also that which is most obscured and is least prolific in fossil remains. The first is due to the slight degree of consolidation of the rocks composing it, in consequence of which it has been everywhere denuded to a low level, and subsequently covered up by superficial deposits to a depth generally greater than that of the natural drainage system, and for the same reason the artificial sections exposed in irrigation wells, (now pretty numerous,) are generally concealed beneath the water line, and the only materials furnished to the Geologist are the lumps of debris thrown out of such excavations.

Lower beds of group.

From an examination of these, and the few nullah courses in which the rocks are exposed, it appears that the lower part of the group, (of a thickness not ascertainable but extending over a horizontal area of about 3 miles in width,) consists of sand or sandy shale, sometimes argillaceous, and

more rarely conglomeratic, the pebbles, as well as the finer materials, being derived solely from the crystalline rocks. Such a conglomerate is seen in some wells at Pudupakkum, 2 miles from Valudayur, where it is partly consolidated into hard masses of grit, but in most cases the sand is quite soft and easily excavated with the native shovels. In a nullah between Vanoor and Catarakuppum it appears as a hard sandy shale, as usual without any fossils, and to the North, in the neighbourhood of Talaveram, there appears to be some calcareous rock, as is evidenced by the great quantity of calcareous debris (kunkur) in the low parts of the soil, which are excavated for lime by the natives. The underlying rock is not visible at this latter place.

Higher beds.

As we ascend to the higher beds, or to speak more strictly, as we proceed Eastwards across this strike, the deposits become finer in grain and more argillaceous, but excepting the occasional occurrence of imbedded concretions, they are equally unconsolidated with the sands below. An arenaceous clay is seen in the nullah South of Andipaleyam, which, judging from the general direction of the strike, must be below the noduliferous clay shale which occurs to the South. The nodule band or bands, for there are probably more than one, are not seen North of Royapoothoopakkum, but between this place and Vanoor they may be seen in several wells, and they have been largely used by natives for building rude revetments to their tank bunds, or for paving the sloping rides of the smaller excavated tanks. The limestone of the Arrialoor bottom bed has, however, been more extensively employed for these purposes, being not only more abundant but also far more easy to work. The nodules are again seen *in situ*, in some field drains to the West of Wattampolliam, and from some of these I have obtained fossils identical with those of Valudayur; *Baculites vagina* is here again the predominating species. The nodules average from 1 to 3 feet in diameter, and,

Extent of concretion bands.

as I have already remarked, in the great majority of cases they are unfossiliferous. Owing to this, and to their being tough under the hammer, fossil searching requires much time and large hammers for its successful prosecution. Indeed, so far as I am able to judge, the fossiliferous band occurs only near the overlap of the Arrialoor group, for all the concretions that I have seen elsewhere exhibited, when fractured, no trace of fossil remains. Above the fossil band there appears to be a mass of silty beds without nodules which are seen exposed only in the low ground North of Sydrapet tank. From the absence of any marked stratification, it is impossible to determine their total thickness.

Beds of Arrialoor group.

The beds of the Arrialoor group are in general better exposed than those of the lower group. The bed of calcareous sandstone at its base may be clearly traced from Valudayur as far as Royapoothoopakkum ; its out-crop projecting above the soil, and being elsewhere traceable by the abundance of its calcareous debris; its appearance in the neighbourhood of Valudayur has been already described. It is also well seen on the summit of the slope to the West of Sydrapet tank, where it appears to cap the hill, the surface of which is pitted all over by the little excavations of native quarrymen. From this point the bed may be traced round to the corner of the tank bund, beyond which it disappears beneath the soil, but there is good reason to believe, from the character of the surface, that the whole of the beds to the West of Ossatary tank are an isolated outlier capping the high ground.

Sydrapet.

The bed is again seen as a thick bedded calcareous sandstone at the Western end of Kurasure tank bund. It has a high dip to the West, not less than 20°, but this is evidently quite local, for in the village of Sydrapet, only half a mile distant, it is nearly or quite horizontal, and elsewhere the dip is but small. From Sydrapet it strikes very

regularly to the North-east, and near the Madras road it appears at the surface, and is quarried by the natives. At this place it is a blueish limestone, in color not unlike the nodules of the "Valudayur" beds, but the fossils *Ostrea tegulanea, Gryphœa orientalis,* and others equally characteristic, would be sufficient, even in the absence of stratigraphic evidence, to prove its Arrialoor age. Besides these fossils, which are here very abundant though difficult to extract entire, a species of *Pinna* is very common, and I obtained one specimen of a large annulated *Hamite (H. Indicus?).*

At Wattampollium.

At Wattampollium again it is exposed in a little nullah. *Arca Pondicherriensis* or *Japetica?* the small *Arca (A. Gamana?)* so common at Verdoor, *Gryphœa orientalis,* and *Ostrea tegulanea* and *Fungia filamentosa* are here common. An *Opis,* of a peculiar form, also occurs, which I have not met elsewhere.

At Royapoothoopakkum.

Again, half a mile to the North-east, the same bed appears in the large tank at Royapoothoopakkum, and a small excavated tank in the village is paved at the sides with blocks of limestone principally derived from this bed. These are full of fossils, and being somewhat decomposed, are easily broken up, affording one of the best fossil grounds in the district. The most common species is the smooth *Arca (A. Gamana?)* of which some blocks are almost entirely composed; the valves being generally united. I have obtained also specimens of *Nautilus Bouchardianus, Ovulum, Natica,* a large *Panopœa,* and several shark's teeth, principally of species of *Lamna,* also from the same locality, *Ammonites Indra,* Forbes.

Beyond Royapoothoopakkum the bed may be traced for some miles by the usual indications of scattered fragments, though nothing is seen in place, and at length in the waste channel at the East corner of Ryproempakkum tank, the out-crop is seen for the last time dipping to the

South-east. Beyond this nothing further is seen, the whole of the older rocks being concealed beneath the thick recent deposit of the Mercanum alluvium.

Thickness of limestone at base of group.

This bottom bed of limestone or calcareous sandstone is the only hard rocky band I have met with in the Arrialoor beds of Pondicherry, and this appears to vary both in mineral character and thickness. What may be the maximum thickness I have no means of ascertaining, as an entire section is nowhere exposed. The greatest thickness that I have seen either in a native quarry or in a natural out-crop does not exceed 5 or 6 feet, and it is probable that the total thickness is nowhere more than double this amount; to judge from the extent of ground occupied by its out-crop. It has been largely quarried at several places, both for local purposes and for the paving of Pondicherry, for which this stone has been largely used, and the principal supply has been undoubtedly obtained from the neighbourhood of Sydrapet, where it occurs within the French territory.

Higher beds.

The beds which immediately succeed the limestone beds over a horizontal distance of more than half a mile are nowhere exposed, but beyond this soft clays and argillaceous sand are seen in several of the nullahs which carry off the drainage of the high sandstone ridge of the Red Hills. Some of the best sections are those to the East of Ossatary tank, where a considerable thickness of argillaceous sand occurs, full of the casts of small fossils, both bivalves and univalves, associated with which is a little hemispherical Bryozoon in great abundance. Both the nature of the deposit and the position of the fossils indicate that the former is an accumulation of comparatively still water, or at least of a sea free from strong and variable currents, and that the shells either lived where they were imbedded, or were drifted but for a short distance. They are never accumulated in nests or lines of false-bedding as in the blocks of the Vanoor limsstone or the limestone beds of the Trichinopoly

group; but are distributed pretty equally through the mass of the deposit.

Thickness of Arrialoor beds doubtful.

It is impossible to ascertain with any certainty the total thickness of the Arrialoor beds of Pondicherry, but, judging from the low angle of their dip, wherever it is ascertainable, and the small extent of country occupied by their out-crop, they must be very much thinner than in the district of Trichinopoly. If we assume the average angle of their dip to be 2°, which is probably in excess of the truth, we should have a thickness of 900 feet of beds exposed to the West of the Red Hills, where they dip beneath the coarse ferruginous sandstones of the Cuddalore group, but any such estimate must be fallacious in the case of such beds.

Generalizations on the Arrialoor Group.

Palæontological distinction of Arrialoor Group.—We have seen in the foregoing pages that while the Palæontology of the Arrialoor group indicates a change of some magnitude at the close of the Trichinopoly period, in the sudden disappearance of certain species and the first appearance of others, there is but little evidence of any corresponding interruption in the stratigraphical sequence of the deposits, nor is there any sudden change in their mineral character, such as would imply important change in the physical conditions of the area. There does not appear to have been any upheaval of the Trichinopoly deposits, in the interval, which, to judge from the indications of the fossils, must have elapsed at the close of the Trichinopoly period. In the South the deposits of the two groups appear to pass into each other, or at least no definite demarcation can be discovered in the almost unfossiliferous and irregularly bedded sands which lie at the junction of the groups: and further North, where both formations become more irregularly bedded, the strike and dip of the two groups, with one exception, is, so far as they can be ascertained, identical. At only a

Physical relation of Arrialoor and Trichinopoly groups.

few points indeed, is the base of the Arrialoor group already marked by its fossil contents, *viz.*, to the North-east of Koloture, in the nullah to the South of Kurribiem, and in the two nullahs to the East and North of Veraghoor. In most of these cases, however, the sections are not clear enough to enable one to examine the actual junction of the beds in section, and it may be that a slight unconformity exists, which I have been unable to detect. In the nullah to the East of Veraghoor an unconformity is indeed indicated by the difference of dip, that of the Trichinopoly beds being from 6° to 8°, while the lowest beds of the Arrialoor appeared to dip at 3° only; but the beds are only exposed in the bed of the nullah, and being waterworn, no great dependance could be placed on this observation. A short distance beyond the dip was clearly ascertainable, and as much as 6°, or about the same as that of Trichinopoly group. I am inclined to believe that were the beds further North, near the final overlap of the Trichinopoly group, better seen, the unconformity which probably exists would be more clearly established, as the narrowing of the Trichinopoly out-crop in this direction is much more rapid than can be reasonably accounted for by the thinning out of the deposits, and must be due to the Trichinopoly group being gradually overlapped. The same thing probably takes place as far South as the deposits are distinctly bedded, the fact not being ascertainable, owing to the obscurity of the Geological features.

Unconformity of groups.

The Arrialoor group overlaps the Trichinopoly group at both extremities. If, therefore, there were no denudation of the latter in the interval of their formation, the Arrialoor period was simply one of further depression, and of extension of the sea area, and the preceding interval, indicated by the change of the fauna, may have been simply one of statical conditions during which no deposit took place in the area now exposed by denudation.

Conditions of interval.

At the same time I am not prepared to assert that no denudation of the Trichinopoly formation preceded the formation of the Arrialoor group, but simply that the evidence obtainable is insufficient to warrant such a conclusion.

Conditions of Arrialoor period.

The greater part of the Arrialoor group gives evidence of tranquil deposition probably in a sea of no great depth, for irregular deposits supervene at one point (in the case of the bone beds) nearly in the middle of the group, and moderately coarse sands occur at intervals throughout the greater part of the group.

Thinning out of deposits towards the North.

The same cause, whatever it was that produced the unequal distribution of deposits during the Trichinopoly period, their great accumulation in the Southern part of our area, and their rapid diminution towards the North, continued to operate throughout Arrialoor times, so that beds, which, in the North of Trichinopoly, have an outcrop of 8 miles in diameter with an average dip of between 1° and 2°, are represented near Pondicherry by beds a few feet only in thickness. This fact, which is indicated by the converging strike of the beds, will tend to explain the concurrence near Pondicherry of fossils characteristic of the higher and lower fossiliferous zones of the formation in Trichinopoly. I cannot say whether these fossils were actually intermingled in the same bed, inasmuch as but very few of them were found *in situ*, and most of them were collected by natives, whose ideas of locality in such matters are not very definite, but their matrix is identical, and I can entertain no doubt that they are all from the limestone at the base of the Arrialoor group.

Intermixture of fossils.

Relations of Pondicherry beds.

With regard to this point it must be observed that only a small proportion of the fauna of the upper zone of Trichinopoly occurs at this locality, intermingled with a small proportion also of that of the lower zone in the same

district. It may be further remarked, that the upper fossiliferous zone has not been traced through the Verdachellum area, and that the greater part of the beds there exposed appears to represent a portion of the unfossiliferous central zone of Trichinopoly. The Pondicherry beds above alluded to may be there also in great part a representative of this portion of the formation in which some of the fossils occur locally, including some of the earliest forms of the upper zone fauna.

Mineral evidence.

The unusual character of the Pondicherry beds tends to bear out this supposition, inasmuch as the greater part of the formation above the bottom limestone, and especially the beds exposed to the East of Ossatary tank, are identical with the sandy clays with casts of small fossils which immediately underlie the Megalosaurus bone bed of Trichinopoly, and are intercalated in the lower part of the sand of which the unfossiliferous zone mainly consists. If this be the case, we must infer that to the North of Verdachellum the Arrialoor formation decreases in thickness much less rapidly than in Trichinopoly.

Lapse of time indicated by change of fauna in higher zone.

The Arrialoor group of Trichinopoly evidently represents a very long period of time, a period sufficient to allow of the local extinction at least of an entire fauna, and its replacement by new forms. It would be too much to assert, indeed, that the lower fauna became universally extinct in the interval, but even a local change so entire must require a long period of time for its accomplishment if unaided by important local changes of physical condition, and of such we have no evidence: and, moreover, the parallelism of the change with that between the white chalk and Mæstricht formations of Europe indicates that the change of fauna is cyclical and not episodical in its character.

CHAPTER XI.—*Cuddalore Sandstones.*

Extent of the formation.

WITH the exception of the alluvial deposits, the formation which I have termed the Cuddalore sandstones is the most recent sedimentary formation in this part of the Carnatic. It overlies all the Cretaceous rocks to the Eastward, and probably extends both in a North and Southerly direction beyond the limits of the area herein treated of. Beds similar in lithologic character and classed by Newbold with this formation, are also met with in the neighbourhood of Madras, and, according to Newbold, to a considerable extent in the low country still farther North. The same formation also extends to the South of Tanjore, though of its limits in that direction we are ignorant; and it is, moreover, a question for future consideration whether parts of the lateritic deposits of the low country of the West Coast be not of equivalent age to the sandstones of Trivicary and Cuddalore.

Characters of the surface.

The area occupied by this formation is more elevated than any part of the surrounding country. It is generally covered thickly with a ferruginous sandy soil, known as "*lal,*" or red soil, and as, from its elevation, it is dry and but rarely capable of irrigation, the greater part of it is abandoned to jungle, which in some parts is very dense, although of stunted growth. The rocks are only seen at rare intervals, chiefly on the edges of the elevated ground, which is frequently bounded by a little escarpment such as that figured in Plate II. *(frontispiece.)* The formation consists in a great measure of grits and sandstones: thin beds of clay are occasionally intercalated, but are rare; and the whole formation is characterized by its ferruginous character, the sandstones, clays, &c., being tinted of all hues of yellow,

Mineral character.

red, brown, and purple. This is doubtless in part due to infiltrations from the surface, the red soil and laterite (which in this part of the country is for the most part only a local form of the red soil,) being the original source of the iron, but much of the iron must have been introduced contemporaneously with the formation of the beds, as they have occasionally highly ferruginous bands intercalated with them, and in general the whole mass is evenly tinted with the peroxide of iron to an extent that can scarcely be due to superficial infiltration. There is also a considerable quantity of carbonate of lime, distributed through the beds, in the form of irregular pipe-like concretions, which penetrate the coarser beds in every direction. These may be due to the segregation of the calcareous matter originally disseminated through the rocks, or they may have been derived from calcareous accumulations, (broken shells, &c.,) which have covered the surface at some period subsequent to the denudation of the country.

Unfortunately no sections are exposed of sufficient depth to enable us to ascertain whether such infiltrations are merely superficial; but the fact that these tubular concretions are chiefly confined to the coarse grits at the base of the group, leads me to infer that the former is the more probable explanation of the phenomenon.

Silicified wood the only organic remains.

The Cuddalore sandstones are generally unfossiliferous. Indeed, the only exception to this rule is that already noticed by Captain Newbold, Mr. Kaye, and others, *viz.*, the occurrence of large trunks of silicified wood at the base of the group at Trivicary and other places near Pondicherry, and of fragmentary plant remains, too poorly preserved however to be determinable, not far from Trivicary.

Bedding.

In general the bedding is not very clear, but, when visible, it is either horizontal, or dips very gently to the East, (*i. e.* seaward) at an angle not exceeding 2°. In Trichinopoly it must rest very nearly horizontally on the Cretaceous

beds, to judge from the outliers which cap the Cretaceous rocks, at about the same level, at several places to the West of the main formation.

Detailed description of group.

It will not be necessary to enter into much detail in the description of the Cuddalore group, as it presents few features of interest, beyond those already noted; and I shall confine myself to a brief notice of the principal localities at which it may be studied within the limits of our area.

At Tanjore.

In the neighbourhood of Tanjore are some coarse grits and conglomerates, which I have referred to this group, although, as stated in a previous chapter, I cannot consider their age as indisputably settled. They are exposed to a considerable extent in the neighbourhood of Vellum, and the moat of the old fort exhibits a fine section of them to a depth of about 20 feet. They consist of false-bedded sandstones and grits, mottled with irregular ferruginous infiltrations, and in some places passing into laterite to a depth of 6 or 8 feet from the surface. Where laterite is formed the rock appeared to be more argillaceous than elsewhere. Bands of conglomerate are also intercalated, chiefly containing quartz-pebbles of various tints, (cairngorum, amethyst, and rock crystal,*) and at one spot several great blocks of cretaceous chert, similar to those in the sandstones near Thaloor (page 142), and containing a few fossils. Messrs. King and Foote, who first noticed these, obtained from them some specimens of Cidaris spines, (impressions) and a cast of a terebratula and some other small fossils (all of which were subsequently lost in the ship which was conveying them to Calcutta). These blocks of chert are, I think, imbedded in the conglomerate, and have not been formed *in situ*, inasmuch as although of large size, (measuring 3 or 4 feet in diameter,) they contain no pebbles, and their sandy base appears to be of finer grain than that of the conglomerate bed in which they are enclosed.

Enclosed chert boulders.

* These are collected by the natives, and several lapidaries in the village of Vellum find employment in cutting and polishing them for sale.

Laterite bed at Vellum.

Two miles South of Vellum a bed of laterite, which is exposed at the surface, (and probably belongs to the Cuddalore beds,) is largely worked for building purposes by the natives. It is, when freshly cut, a porous, ferruginous, sandy clay, which hardens on exposure to the weather, and only after some months becomes brown and glazed on the surface, in the manner characteristic of laterite.

Extent of formation South of the Cauvery.

The group does not probably extend much to the West of Vellum, where it forms a little escarpment such as usually bounds the formation. But as nothing is seen of any rock for some miles to the Westward, owing to the thickness of the soils which cover the face of the country, its exact limit in that direction cannot be ascertained. To the Eastward it extends as far as near Pamani and then disappears beneath the alluvium of the Cauvery delta, which also bounds it on the North ; but to the South it appears to extend into Tondiman's country, and how much further is not ascertained. The only other good section exposed to the South of the Cauvery, besides that of Vellum, is in the moat of Tanjore, the fort of which stands just on the Northern edge of the formation, overlooking the delta of the Coleroon and Cauvery.

Formation North of the Coleroon in Wodiarpolliam.

In the Trichinopoly district, North of the Coleroon, the formation reappears to the South of Wodiarpolliam, and occupies the greater part of the talook of the same name. Its occurrence at Kondamungalum, where it forms a very fine escarpment from 60 to 80 feet in height, has already been described. Beyond this very little is seen as far as the Vellaur, where a fine section of the lowest beds, of about a mile in length, is exposed in the bank of the river, above Plaunthoray. The rock which is here a soft sandstone, is mottled white and pink. The latter, which is the prevalent color of the rock, being due to ferruginous infiltration, while the former marks those spots where

At Plaunthoray.

calcareous infiltrations have resisted the absorption of the coloring fluid. The rock, in consequence of the unequal resistance of its parts, weathers into a roughly mammillated mass, bearing a rude resemblance to great masses of coral, wherever, as in the neighbourhood of nullahs, the surface is laid bare, and much exposed to the action of rain. Higher up, on the high ground between the two villages of Plaunthoray, some of the sandstones are silicious; but these are exceptional.

East of Wodiarpolliam.

Of the beds to the Eastward I have seen but little, for the reasons noted above. The rock thrown up from an ancient irrigation channel about 4 miles beyond Jahenkoondasholapooram (East of Wodiarpolliam), is a fine soft argillaceous sandstone, mottled grey and yellow, and undistinguishable from much of the Cretaceous rocks. Indeed but for its position I should have considered it to be Cretaceous.

At Verdachellum.

To the North of the Vellaur, the Cuddalore sandstones are met with in the immediate neighbourhood of Verdachellum, and are exposed in some quarries, almost the only excavations deserving the name in this part of the country, and situated half a mile to the East of Velur (Wurnaur of the Atlas map). The rock consists of a massive yellow sandstone, tolerably hard, and well adapted for building. The surface has been very unevenly eroded, and it is covered with from 6 to 20 feet of red soil, at the base of which is a layer of rounded quartz pebbles. No bedded structure is discernible, but the rock is intersected by 2 series of regular vertical joints, at right angles to each other. The quarries are situated just above the little escarpment or steep rise, which runs from near Velur for some miles to the North-east, and along which the beds are exposed at two or three places. At Kovilaveram a section is seen in a small gully draining the high ground: the rock is a mottled sandy clay, not unlike that of the Cretaceous beds to the Westward, but containing some very characteristic bands of ferruginous grit. The

escarpment does not coincide with the boundary of the formation which passes below it a little to the Westward.

Paroor outlier.

A large outlier of Cuddalore sandstones occupies the high patch of jungle to the East of Pulliyur (Paroor of Mr. Kaye's Memoir). The beds, consisting of coarse ferruginous grits, are seen in the bank of a little jungle road leading Eastward from the village, and masses of ferruginous grits are seen strewn over the surface between that village and Veramanur. Further North nothing is seen in place, owing to the thick covering of red soil and laterite, on which the Acacia jungle grows very thickly; and the boundary is drawn partly in accordance with the form of the ground, and partly with such indications of the presence of the Cuddalore beds as are afforded by their lateritized fragments strewn on the surface.

Main formation—Motepolliam.

To return to the main formation : at Motepolliam a fine section of the lower beds is seen in the bank of the waste channel at the North-east corner of the large village tank. But neither here nor elsewhere in this part of the country, is the absolute junction of the Cretaceous beds and Cuddalore sandstones exposed. At the bottom of the section is a coarse sandstone, which is followed by a band of hard white sandy clay, (or rather sand of extreme fineness, as it has no plasticity,) irregularly interbedded, and at the top is a conglomerate also very irregularly deposited, and containing, not only pebbles of gneiss and quartz but also of the white sand itself which immediately underlies it. Such occurrences are not uncommon in beds of irregular deposition, and I have noticed a similar phenomenon in the Talcheer beds of Cuttack. I have never met with any clay resembling the above in any part of the Cretaceous rocks ; and I cannot doubt that although the clay and conglomerate beds belong to the same formation, the former was the source from which the clay pebbles in the latter were derived.

To the North of Motepolliam the boundary of the formation bends off considerably to the Eastward, and, between that village and Vellumpaleyam, again rises into a little escarpment, which continues with few interruptions from this point to beyond Cuddalore. At Vellumpaleyam some quarries have been opened by the natives, who use the stone chiefly for the manufacture of rice-mortars, and for the construction of revetments to their tank-bunds. The stone is a coarse soft white sandstone, not very homogeneous, but easily worked. The bedding is not well marked, but appears to dip 1° or 2° to South-east, and the rock is intersected by two sets of joints which much facilitate quarrying operations. One of these varies from E. by N. to E. N. E. and is very distinct, the joints being 4 or 5 feet apart, but rather irregular.—The other is less distinct, and the joints more distant. It runs North by West, and is therefore about at right angles to the first system.

Scarped boundary along the Guddalum.

Formation at Vellumpaleyam.

A large outlier, in part bounded by an escarpment, covers much of the Cretaceous rocks to the West of Vellumpaleyam, but offers nothing worthy of special notice.

Chendamungalum outlier.

By the side of the road which crosses the Guddalum, South of Panurutti, (near Tiruvadi,) a gully cuts deeply into the Cuddalore beds, about half a mile from the South bank of the river, exposing a white hackly clay, which is used by the natives in the neighbourhood for making their caste marks. I examined it closely, in the hope of finding plant remains, which occur in a very similar clay near Trivicary, but without success. Opposite Tiruvadi the Cuddalore beds are well exposed in the bank of the river. They are soft grits of a pink-tinge, and somewhat pebbly: as usual they are covered with 12 to 15 feet of red soil.

Formation at Panurutti.

At Tirumungalum, (Trivandipuram of the map,*) a very fine section of the beds is seen in the face of the escarpment, which is here not less than 100 feet high. A hard mudstone, containing merely a trace of iron, occurs at the base, and is followed by bands of sand and clay, the latter originally white, but now irregularly mottled with a purple tinge, by the partial infiltration of a ferruginous solution. Some of the sandstone beds are pebbly, the pebbles, which are small, consisting of quartz, originally derived from the gneiss. Some of the beds are very ferruginous, and about half way up the section is a bed of impure ochre. The bedding is tolerably distinct, and, as seen, appears to be horizontal, but the line of section nearly coincides with the strike, and as seen in the turn of the escarpment, the dip of the bedding appears to be at a very low angle to the Eastward.

At Tirumungalum.

From Tirumungalum to Trivandipuram, and on to Cuddalore, the escarpment is very fine, varying from 80 to 100 feet and upwards in height (*see* Plate II.) But the face is in general too much covered with talus to admit of a good sectional view of the beds. Behind the latter village, close to the point from which the sketch is taken, they are, however, well seen in the face of the cliff, consisting of sandstones and grits, mottled pink and white, in a manner much resembling the beds at Plaunthoray, described at (page 168), and owing to similar causes. About 25 feet of the upper part of the section is occupied by a bed of very ferruginous clay, much resembling that at Vellum (page 168), and half converted into laterite. It appeared to belong to the Cuddalore formation, but I was unable to ascertain this point to my perfect satisfaction, owing to the upper part of the section being much broken and obscured by debris. At the top the clay passed into a grit, and became more ferruginous than the lower part, but the laterite structure was very distinct. Debris of a similar rock covers the escarpment beyond, as far as Cuddalore.

At Trivandipuram.

* The real village of Trivandipuram is that marked as Trivandipuram station, 5 miles from Cuddalore.

At Capper's hill, (as the escarpment is termed opposite Cuddalore,) the beds are coarse grits, sometimes white and sometimes ochreous and mottled, and more or less conglomeratic. To the South of the Capper's hill tank the beds are argillaceous, and farther in the same direction, they pass into a nodular ochreous sandy clay, which becomes lateritic at the surface.

At the Capper's hill or Cuddalore.

The escarpment dies away about 4 or 5 miles to the South of Cuddalore, and beyond this little or nothing is seen of the Cuddalore formation, owing to the red soil which thickly covers the country.

South of Cuddalore.

In the village of Andanapet, to the North of Vullupullum, a laterite is seen in some wells, but I could not ascertain whether it was a superficial deposit or a clay bed of the Cuddalore formation.

We now pass on to Pondicherry, where, together with the Cretaceous beds, the Cuddalore group re-appears to the North of the Ariancoopum River. From the South-east corner of Ossatary tank, the plateau known as the "Red Hills," and of a maximum width of 4 miles, extends to Mundakuppum, a village on the coast 10 miles North of Pondicherry. This plateau is bounded nearly all round by an escarpment such as I have previously described, or by a steep slope where the escarpment is wanting, and numerous good sections of the beds are exhibited both on the East and West flanks of the little plateau in the nullahs which carry off its drainage. Again, 6 miles to the West of the Red Hills, a corresponding little plateau of less elevation and not exceeding 1 or 2 miles in width, runs from the village of Trivicary (Tiruvakkerei,) where these beds in question were first noticed by Mr. Kaye, to a distance of 8 miles, parallel with the Red Hills, the intervening valley from which the Cuddalore beds have been denuded being occupied by the Cretaceous rocks previously described.

Red Hills of Pondicherry.

At Trivicary.

At Trivicary, immediately to the East of the village, some low broken hillocks of ferruginous grits rest on the gneiss, which, to the West of the village, rises into the low hills mentioned by Mr. Kaye. At the base the grits are very conglomeratic, and the whole formation is much false-bedded. The rocks are much denuded, and cut up by a number of little gullies, and in the beds so exposed large masses of exogenous silicified wood are imbedded: some of the trunks exposed being 15 or 20 feet long and 5 or 6 feet in girth.* They are all prostrate, but, judging from their state of preservation, have probably not been transported far from the spot where they grew. The grits extend to the bank of the Ariancoopum, in the bed of which they are well exposed, and a small patch of them also crowns the right bank of the river.

Silicified wood.

To the North-east, the Cuddalore beds rest on Cretaceous rocks, which crop out beyond their Western boundary. Near their extremity, at half a mile to the North-west of the village of Konipet, a hard marly bed is exposed in some broken ground, full of fragmentary plant remains. These were, however, very imperfect: they consisted chiefly of broken stalks, with one or two specimens of what appeared to be seeds and buds; some appeared to be portions of exogenous leaves, but I could not clearly determine the nature of any of those fragments.

Plant-bed, Konipet.

The rocks comprising the Red Hills to the East of the Cretaceous area closely resemble those at Trivicary. In several small nullahs to the East of the Ossatary tank, they are seen resting on the denuded surface of the Arrialoor beds,

Red Hills.

* This wood has been described and figured by Professors Schleiden and Schmidt of Jena, (Über die Natur der kiesel Hölzer) under the name of *Peuce Schmidiana.* Captain Newbold mentions the occurrence of a trunk 100 feet in length. The locality was first described, and a sketch published by Captain John Warren in 1810. *As. Researches*, Vol. XI., page 1. He mentions a tree, parts of which existing *in situ* showed that the perfect trunk must have been 60 feet in length: its diameter at the smaller end, where inserted in the rock, 2 feet, at the bottom of the trunk 4½ feet, and at the roots, where broadest, 8 or 9 feet.

affording the only instances of the visible junction of the two formations that I met with either in South Arcot or Trichinopoly. The base of the Cuddalore beds, which are here nearly horizontal, is marked by a thin band of hard ferruginous shale. Above this, in the base of the beds, which are everywhere somewhat ferruginous, occurs a conglomerate full of small pebbles of quartz and gneiss. A few fragments of silicified wood are also met with, but neither in such abundance, nor in such large masses as in the beds of Trivicary. The Cretaceous rocks in the lower part of the section are composed of pink and white sands, chiefly to be distinguished from the overlying Cuddalore beds by their finer grain, and the occasional, though rare, occurrence of an intercalated fossiliferous band.

Mineral character.

The Cuddalore beds are coarse in grain, consisting of comminuted garnet, quartz and magnetic iron, with specks of dark mica cemented by ochreous clay and kaolin, the former probably derived from the Cretaceous rocks; the latter from the felspathic portions of the gneiss and the associated granite veins.

Eastern slope of Red Hills.

To the East of the Red Hills the beds composing them are well seen, where the high road from Madras to Pondicherry decends the little escarpment which forms their boundary against the alluvial deposits of the coast. The best and most continuous section is, however, seen in a nullah which drains into the sea at Bommayapaleiyam, after cutting through the Cuddalore beds for about a mile, to a maximum depth of 20 feet. The rocks seen in this nullah are deep-red sandstones, with occasional lenticular patches of conglomerate of a lighter color. The whole are false-bedded, and I did not observe any case of true bedding from which the general dip could be ascertained. Along the coast the formation terminates in a very decided escarpment, running immediately to the West of the coast road, only distant about a furlong, or, at the utmost, a quarter of a mile

from the sea; which interval is occupied by the shifting sands of the coast. . The base of the escarpment, as at present seen, is probably not less than 20 feet above the actual level of the water in the bay.

General Remarks on the Cuddalore Group.

Physical conditions of country during Cuddalore sandstone period.

It will be seen from the foregoing description that the Cuddalore sandstone formation must have been formed at a period when the principal physical features of the surrounding country were much the same as at present, with the exception that a large part of the actual plains of the Carnatic must have been below the level of the *sea*. The perfectly undisturbed bedding and nearly horizontal position of the underlying Arrialoor beds prove that since the middle of the Cretaceous period, no great disturbance has affected the country in question, and although more than one great elevation and depresssion has increased or diminished the land area since that period, such changes were in all probability equable and extensive in their effects, and were unaccompanied by local disturbance of a violent character. Under these circumstances we might expect the Cuddalore formation to have been originally of considerable extent, and covering the greater part of the plains of the Carnatic, and being the most recent formation, (of any thickness,) of which we have any knowledge, we might expect to find other remnants than those herein described scattered over the low country in question.

Probable extent of the formation.

Difficulty of identifying it.

Unfortunately we have no certain means of identifying the formation in question. Its typical mineral character, that of ferruginous grits, sandstones, and conglomerates, with occasional beds of white clay, is no less characteristic of many of the sedimentary formations of India, some of which can be proved to be of very ancient date; and similarity of position, combined with the negative indications of there being no proof of greater antiquity, is the best evidence of identity obtainable. On such evidence

however we may with considerable confidence trace the Cuddalore sandstone formation considerably to the North of the area described.

I should, in the first place, mention that although I did not visit the coast to the North of the Mercanum alluvium, an elevated ridge covered with red soil, which I have no doubt is the continuation of the Cuddalore formation, appears in that direction; and very possibly extends for some miles Northwards. Beyond this I am not aware of the occurrence of any sedimentary rocks as far as Madras, 8 miles to the North-west of which is a sandstone formation well known as the "Red Hills," and considered by Captain Newbold* to have been at one time continuous with the "Red Hills" of Pondicherry. This formation, according to the same author, covers an area of 50 square miles, forming "an undulating tract elevated usually 40 or 50 feet above the general level of the country." These beds, like a large part of the Cuddalore formation of South Arcot, are either covered by laterite of more recent formation, or have a portion of their surface beds converted into that rock. Again to the West of Madras, between Poonamallee and Stripermatoor, a sandstone formation occurs, bounded by a little escarpment about 40 feet high, and in its mineral characters closely resembling the Cuddalore formation. Like the "Red Hills" of Madras, it was regarded by Captain Newbold as contemporaneous with the beds of Trivicary, but at a later period some beds, apparently belonging to this formation at Stripermatoor, were stated by the Messrs. Schlagintweit to contain remains of zamias (a statement which I had subsequently an opportunity of confirming). The remains met with by myself were very fragmentary, and apparently not plentiful. They were imbedded in a laminated white clay which appears in a nullah 1 mile to the South of the village, and dips apparently 4° or

Extent North of Mercanum.

At Stripermatoor.

Zamia beds.

* Journal Asiatic Society of Bengal, Vol. XV., page 204—206.

5° to the South. The occurrence of zamias at this locality would indicate that the Stripermatoor beds, at least, are older than the Cuddalore formation, in which, as I have mentioned, exogenous plant remains only have been met with (excepting some grass-like remains); but, until the physical Geology of these beds has been worked out, we cannot affirm that the laminated clays of Stripermatoor are not considerably older than the ferruginous formation which forms the escarpment near Poonamallee.

Possibly two distinct groups.

I content myself with pointing out this possibility as a matter of some interest for future investigation. I am unable to say what is the extent of the sandstone formation in question. From a remark of Captain Newbold it would appear to extend to the South-west as far as Conjeveram at least, a distance of 30 miles; but I have seen no definite statement upon the subject.

At Parmaulnaigpet.

Beds similar to the above occur also, according to Newbold, at Parmaulnaigpet, about six and a half miles to the East by South of Tripassore and a little North of the road from that place to Madras, to the West of which it lies.

In Cuttack.

I have not seen any notice of this formation in the district of Nellore or further North in the Northern Circars; but this part of the coast has not yet been at all closely examined. Beyond the Chilka lake, a formation very similar in character has been described by my brother in a former volume of the Memoirs, and it is suggested by him, on physical grounds, to be a comparatively recent formation, although unfossiliferous, and not associated with any beds of ascertained age.

Southern extremity of Peninsula—Ceylon.

Ofthe Southern part of the Peninsula, as I have already mentioned, we know but little. A part of the coast of Tinnevelly, Ramisseram Island, the Island of Jaffna, and much of the skirts of Ceylon, consist of a comparatively recent marine formation, most if not all the fossils of which are of living

species.* Whether this be a local form of the Cuddalore sandstone formation or of the more recent date of our marine alluvia, I cannot venture to opine. It is not improbable that the depression evidenced by the former, and the elevation of which, as I shall hereafter endeavour to show, the red and black soils so frequently referred to in this Memoir, are the existing records, may have been immediately consecutive, being the initiatory and concluding events of a period of widely extended marine conditions, of a part of which the Tinnevelly and Ceylon deposits are also local records. The full discussion of this question would, however, lead me into a review of the tertiary and alluvial formations of a large portion of the Peninsula, but this is a subject entirely foreign to that which forms the substance of the present Memoir.

Marine deposits on the West Coast.

I should, however, mention before concluding, that marine deposits apparently contemporaneous with those of Tinnevelly and Ceylon, occur in Katywar. There are also various superficial deposits on the West Coast, part of which, at all events, may eventually be correlated with the Cuddalore sandstones,† but these have so far, as I am aware, never been carefully examined with a view to their classification, except perhaps those immediately in the vicinity of Bombay, the elucidation of which we owe to Dr. Carter.

* I have seen specimens of these from Jaffna in the form of casts, in a calcareous sandstone, the whole of the shell having disappeared. It is an instructive commentary on the common popular idea that the state of fossilization bears a certain relation to Geological age, to contrast such specimens as these with the shells of the Trichinopoly limestone, which possess all their pristine polish, and sometimes even traces of the original coloring.

† This has been attempted by Dr. Carter in his Summary of the *Geology of the Peninsula of India.* He has, however, fallen into a serious and somewhat incomprehensible error in regarding the Red Hills of Pondicherry as a formation distinct from that of Trivicary. *Geological papers on Western India*, page 753.

CHAPTER XII.—*Soils and Superficial Deposits.*

THESE, as occurring in Trichinopoly, South Arcot, and Tanjore, may be classed Geologically under 4 heads, *viz.* :—

1. Those formed by the decomposition of the rock *in situ.*
2. The fluviatile alluvium.
3. Regur.
4. The sandy soils of sedimentary origin generally more or less ferruginous, and frequently containing pisiform nodules, which, when very abundant, are sometimes cemented together into a form of laterite.

The soils of the first class are of rare occurrence, *per se.* They are confined to certain tracts on the gneiss, and I have met with but one case, *viz.*, near Thutchuncoorchy, within the area of my own survey, in which it could be decidedly predicated that the surface soil was formed solely of the rock decomposed *in situ.* The gneiss of the Northern part of Trichinopoly (in the neighbourhood of Volcondahpuram) is so decomposed to a depth of many feet that it is reduced to a sandy gravel, but this is covered with ochre varying in thickness from one foot upwards. In other places gneiss equally decomposed is covered with ferruginous soil, as in the case of the accompanying section, Fig. 16, that

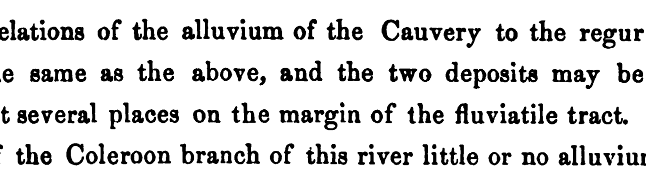
FIG. 16. SECTION OF RED SOIL IN GRAVEL PIT NEAR KYDOOR, S. ARCOT.

s, Ferruginous sand; 1 to 2 feet: *g'*, angular gneiss: *g*, decomposed gneiss.

of a small gravel pit near Kydoor, in South Arcot, but in this case, and probably in most others, the red soil was of subsequent formation.

Alluvium of fluviatile origin occupies the delta of the Cauvery to the South of the Coleroon branch, a large part of the flat tract intervening between the Guddalum and the Ariancoopum, and narrow strips bordering the larger streams. It is usually a pale sandy loam, and whenever a supply of water is obtainable, is brought under paddy cultivation. In many places it is now above the flood levels of the country, and in the alluvial and regur covered tract to the South of Verdachellum, the fluviatile alluvium, which borders the Mani Múkta and the Vellaur, is at a higher level than the regur which occupies the intervening area. In a section of the river bank at Sattyavadi, on the Vellaur, 20 feet of fluviatile alluvium is exposed, resting on 3 or 4 feet of regur. The alluvium is highest close to the bank of the river, and extends thence (at the place mentioned) about 2 miles to the Northward, the surface gradually declining to that of the regur. A section across the alluvial tract at Sattyavadi would probably show the relations of the soils to be such as are exhibited in the accompanying section. Fig. 17.

FIG. 17. DIAGRAM SECTION ACROSS THE VALLEY OF THE VELLAUR RIVER.



a. a., Fluviatile alluvium : *r. r.*, regur : *l. l.*, red soil (Ferruginous sand).

The relations of the alluvium of the Cauvery to the regur are precisely the same as the above, and the two deposits may be seen in contact at several places on the margin of the fluviatile tract. On the North of the Coleroon branch of this river little or no alluvium is met with below a point a few miles below Lalgoody; beyond this the left bank of the river is formed by the regur which is seen at a higher level than the fluviatile alluvium of the delta.

I have stated above that the fluviatile alluvium consists principally of a pale sandy loam, called by the natives *masab*. Some other forms of deposit are, however, met with in the broad expanse of the Cauvery delta and elsewhere. Thus to the East of Sheally a dark sandy loam is the prevalent soil, and a bank section of the Vellaur River at Tolum, (North of Chellumbrum,) exposes beds of black mud and peaty matter, apparently a marsh deposit, alternating with beds of sand probably formed by the river. Two sections of this bank at different spots are as follow:—

SECTION I.—*Total depth* 12 *feet.*

3 feet of pale sandy alluvium with *Melania spinulosa.*

5 feet of black mud with *Ampullaria globosa, Paludina melanostoma,* and *Bithinia pulchella.*

3 to 5 feet white sand.

SECTION II.—*Total depth* 12 *feet.*

3 feet pale sandy alluvium with a few shells.

3 feet black mud with shells. *Bithinia marginata,* &c.

1 foot alternations of black mud and sand.

4 feet white sand.

4 feet bluish black mud, with root-like calcareous concretions and shells, *viz., Bithinia marginata, B. pulchella, and Paludina melanostoma.*

A peaty deposit noticed by Messrs. King and Foote is exposed in the bed of the river at low water at the base of the above sections, and was not uncovered at the time of my visit.

Tolum is situated at about 4 miles from the sea, and, except during floods, the water is quite brackish, so that mud deposits with fresh water shells must have been formed under different local conditions from those which now obtain. The *Ampullaria* and *Bithinia* are characteristic rather of still water such as that of a marsh, than of a river, while *Melania spinulosa* of the upper bed of sandy loam is more common in rivers than in tanks or other accumulations of still water.

3. *Regur.*—The soil known as regur or cotton-soil covers a large area in Trichinopoly and South Arcot. Its most characteristic form is a black or bluish black tenacious mud, which, after prolonged heavy rain, is almost impassable even to a pedestrian, while, after a long continuance of dry weather, it is seamed in every direction with gaping cracks which frequently extend to a depth of many feet. In some parts of India this soil is remarkable for its fertility, but such is by no means the case in Trichinopoly. Until the recent reduction of the land tax, the greater part of it was left uncultivated, and on its hummocky rough surface, little else grew than tufts of dry wiry grass and a few low shrubs, such as *Jatropha glandulifera,** *Acacia auriculata, Ninum oleander,* with *Sanseviera Zeylanica,* and *Argemone Mexicana.* When cultivated, cotton, and occasionally castor-oil, and some of the poorer grains, such as varaghoo, are its chief products.

Common mineral character of regur.

Fertility.

Other forms of regur that I have met with are a stiff black clay, which is, however, not very commom, and occurs interbedded with the more common variety of the soil and clay or mud of a pale grey or yellow color, the latter on the Cretaceous rocks only, and evidently owing its color to an admixture of the Cretaceous clays beneath.

Exceptional forms of regur.

No fossils have been met with in the actual regur, but a deposit of estuarine shells, into which the regur passes near Porto Novo, will be noticed further on; kunkur is common, and when it occurs on the Cretaceous rocks, is probably in part derived therefrom: it appears, however, generally to be of original formation in the regur.

* For the identification of these and other plants mentioned in these pages I am indebted to my friend Dr. T. Thomson.

The thickness of this soil is very variable. On much of the gneiss country it does not exceed 1 or 2 feet, but I have noticed elsewhere sections of 10 or 12 feet, as on the watershed of the Vellaur and Cauvery Rivers, and it probably attains a much greater thickness in the valley of the former river.

Thickness and structure.

The regur is usually tolerably homogeneous, and exhibits little structure. In the ochreous clay of the Ootatoor beds, where, as above mentioned, the lower part of the regur is tinted by the admixture of the local rock, this passes gradually upward into the usual black mud. Elsewhere I have noticed irregular alternating beds of different tints.

As regards the relations of the regur to the underlying rocks, it occurs indiscriminately on the Cretaceous rocks and gneiss, and though I have never seen it in section resting on the Cuddalore sandstones, I believe that it does so on the left bank of the Coleroon, and there can be little doubt that it does in the lower part of the valley of the Vellaur. The mineral character of the lower part, as I have mentioned, is occasionally affected by that of the rock on which it rests, but this is rarely the case for more than 2 or 3 feet, and the character of the soil generally may be said to be independent of that of the local underlying rocks.

The only condition which I have observed generally to determine the occurrence of regur is that of relative low elevation, that is to say it affects depressions in the country irrespective of absolute height above the sea, while the sandy soils and lāl occupy the higher ground. Before however entering into this, which is a most important point, as bearing on the theory of its origin, I will pass on to the description of the sandy soils, the relations of which to regur are such, that it is impossible to avoid the conclusion, that the two soils are due to concurrent causes.

Elevation the determining condition of its occurrence.

4. *Sandy soils.*—Under this head I include the ferruginous sand which covers the Cuddalore sandstones in Tanjore, Trichinopoly,

and South Arcot, and the sandy soil (also generally ferruginous) which in general thinly covers the granitic ridge to the North of the Cauvery, forms a narrow band round the foot of the hills, and is also spread widely over the gneiss of the western part of South Arcot. In the seaboard of the Cauvery delta at Tirmelvassel and to the North of Tranquebar some ridges of ferruginous sand, much resembling the above in mineral character, and probably formed by similar agency, have been mapped by Messrs. King and Foote.

The mineral character of these sandy soils does not vary to any great extent, except in the proportion of iron which they contain, and to which their red colour is due. They consist chiefly of sand with a certain proportion of argillaceous matter. The proportion of iron varies from a mere trace, in the case of the grey sand which frequently occurs at the bottom of the deposit, when the latter is of any thickness, to 20 or 25 per cent. in the case of the lateritic forms of the soil such as occur around Ambapuram on the Cuddalore sandstones to the North of the Murdayaur. The ordinary form of the soil, a red sand, contains, according to two analyses by Mr. Tween, about 2 per cent. of iron, the two specimens being respectively as follows :—

No 1, from Munnagoody, in the Wodiarpolliam talook, Trichinopoly district .... 2·1 per cent.

No. 2, from Punrùtti, on the bank of the Guddalum River, in South Arcot...... 1·46 per cent.

which are equal to 4 per cent. and 2·7 per cent. of hydrated peroxide, the state in which the iron exists in the soils.

Varieties intermediate between this and laterite are very common. These contain small pisiform ferruginous concretions disseminated through the sand, which in an unweathered section of the soil are seen to blend off into the matrix in such a manner that there can be no doubt

they have been formed *in situ*, but when washed out and exposed to the action of the air and rain, assume the shining dark-brown surface characteristic of weathered laterite. This form of the soil is very common on the Cuddalore beds in the North-East of Trichinopoly.

Another form in which the pisiform concretions are so abundant, that when the loose sandy matrix is washed away, they become cemented together as a friable laterite, occurs to the West and North of Vullum in Tanjore, also near Ambapuram (above mentioned), and sometimes on the gneiss as near Madripet to the North of Oolunderpet, in South Arcot.

The section at this last place is as follows :—

Ferruginous sand	... ...	3 feet.
Concretionary lateritic gravel	...	2 feet.

In this bed the iron was very unequally distributed, some parts being much more closely concretionary than others.

The sandy soils frequently contain pebbles of gneiss, quartz, &c., sometimes much water-worn, at other times angular and apparently

FIG. 18. SECTION OF RED SANDY SOIL IN THE VELUR QUARRY, NEAR VERDACHELLUM.

r., Ferruginous sand : r., rolled pebbles : s., Cuddalore Sandstones.

just washed up from the surface of the underlying rock. The accompanying section of the soil resting on Cuddalore sandstones in the

Velur quarry, near Verdachellum, is an illustration of the former case (Fig. 18). The soil, which in the section is 8 feet thick, rests on the denuded surface of the Cuddalore sandstones, the upper beds of which are much broken up, but are quite distinct from the sand above. The pebbles, chiefly of rolled quartz, are confined to the base of the latter, and at this spot are not very numerous. About a mile further to the North, however, on the slope of the little escarpment described in a former chapter, a section of the same soil is exposed in a nullah about the same thickness as the above, but full of quartzose pebbles of all sizes, from that of an orange downwards, arranged in bands which dip with the surface of the escarpment, or at a somewhat less angle, having apparently formed a beach deposit at some former period. Accumulations of similar pebbles cover the surface of the ground around the Cuddalore sandstone outlier near Chendamungalum, sometimes half imbedded in the red soil, and probably derived originally from the conglomeratic beds at the base of the Cuddalore Group.

I have seen rolled quartz-pebbles also imbedded in the red soil in some cases in which it rested on gneiss, as at Madripet, in the lower bed of the section given at page 186.

More commonly on the gneiss the fragments of older rocks imbedded in the red soil are small angular fragments of the local rock. (*See* Fig. 15, page 180.) In this case, as indeed in all others in this part of the country in which I have found red sandy soil resting on gneiss: I have seen no reason to believe that it is formed by the decomposition of the gneiss *in situ*. In the case illustrated in Fig. 15, such is certainly not the case, as the gneiss, although much decomposed, is bounded in section by a distinct line of demarcation; moreover it decomposes into a grey sandy gravel, which is stained near its surface by ferruginous infiltrations from above, so that in any case the iron of the soil must be from a foreign source.

Like the regur, the red soil frequently contains nodules of kunkur, especially when it rests on Cretaceous rocks.

Thickness.

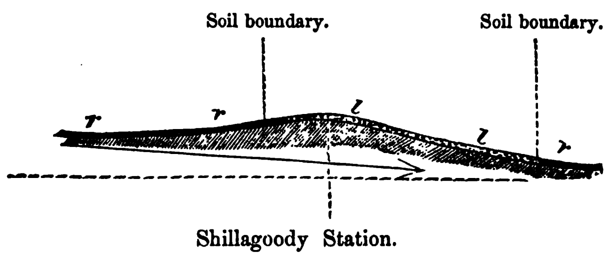
The deepest sections of the red soil I have seen have not exceeded 20 feet; I have observed it of this depth in the Velur quarry above-mentioned, and also in some of the nullah sections in the neighbourhood of Ambapuram. In both these cases it covered Cuddalore sandstones. I have never observed more than 3 or 4 feet of it in section on the gneiss, and it usually does not exceed 1 or 2 feet, but my experience of the country formed by this rock is limited, with few exceptions, to that part lying between the Cretaceous rocks and the Madras road, much of which is covered with regur.

The relations of the red sandy soil to the underlying rocks are as indefinite as those of regur. It occurs on Gneiss, Cretaceous rocks and Cuddalore sandstones, on the latter almost always, except in the river valleys, but this is owing to the fact that the Cuddalore formation occurs most frequently as a little plateau elevated above the average level of the country, and the *presence* of the red sand is thus determined by elevation and not by the nature of the underlying rock. The greater thickness of the sandy soil on the Cuddalore formation, as compared with gneiss, is probably owing to the greater softness of the former rock, which, by denudation, has yielded much of the material of which the soil consists.

From the above description it is evident that the regur and sandy soils are of aqueous formation, as is proved by the occurrence of water-worn pebbles in the latter, and the bedded structure occasionally met with in both. The red soil occupies the higher and the regur the lower ground, and this relation obtains apparently as a general rule elsewhere, as well as in Trichinopoly. Confining our remarks, however, to that district which is especially the subject of this Memoir, we will proceed to consider more in detail the extent and geographical relations of the two deposits.

On studying the distribution of the soils, it will be seen that the sandy soil covers a number of isolated areas surrounded by regur, and a narrow band of the former also runs round the base of the hills. I have already mentioned that the sandy soils affect elevated ground, and that this distribution is determined by local relative elevation irrespective of absolute height above the sea. There is another important point to be noticed in connection with elevation, *viz.*: that with reference to the general fall of the country, as indicated by the drainage system, the red soil descends to a lower elevation on the outer or lower slope than on the inner or upland slope, or in the particular case of those areas which are nearest the coast, the red soil descends lowest on the sea-ward slope. The accompanying diagram section of the Shillagoody ridge will serve to illustrate this. (Fig. 19.) The part of the ridge, across which the section is made, has its Southern slope towards the Cauvery valley and the Murdayaur tributary which runs at

FIG. 19. DIAGRAM SECTION OF SHILLAGOODY HILL, IN TRICHINOPOLY, SHOWING RELATION OF REGUR AND SANDY SOIL.



r., *r.*, regur: *l.*, *l.*, red sandy soil.

The dotted horizontal line indicates the sea level.

The arrow the general fall of the adjoining country.

no great distance parallel with the line of section, runs in the direction indicated by the arrow. Now, on the Northern slope of this ridge, the regur ascends very nearly to the summit level, while the Southern slope is covered with the red soil down to the foot of the ridge, that is to a level of probably not less than 20 feet below its limit on the Northern slope. The difference is, I believe, even more than this, but its exact

amount is comparatively immaterial; the fact, as generally stated above, is undoubted, and is important, as we shall see in considering the origin of the deposits in question.

Leaving now for a time the immediate subject of the soils, it is necessary before proceeding to a full development of the hypothesis of their origin, to call attention to some of the physical phenomena of the country, and especially of the coast which have an important bearing on this part of my subject.

The Pulicat lake near Madras and the Chilka lake between Ganjam and Cuttack are well known instances of those lagoons common on the coasts of India and Ceylon which are enclosed by spits of sand formed by the opposition of the marine shore currents to the out-flow of the land drainage.* The deposit found in these lagoons is for the most part a dark sandy mud, as I have myself observed in dredging the Negombo lake in Ceylon, and the estuary of the Adyar near Madras, and as my brother has noticed in the case of the Chilka lake. This mud bears a remarkably close resemblance to regur, except in the absence of kunkur concretions, which are probably of subsequent formation, the material being furnished by the calcareous element of the deposit. Molluscs are not very common in this mud, and I noticed in the case of the Negombo lake that all that I obtained from the upper part of the lake (*Potamides fluviatile*) were greatly eroded, the dead shells especially, and so decayed, that very slight pressure was sufficient to destroy them. The water of these lagoons is alternately fresh and brackish at different times of the year, and marine species do not, as a rule, penetrate far beyond the estuary by which the lagoons open into the sea.† The commonest species there met with are *Cytherea casta*, Gmelin, *C. meretrix*, Linn, *Nassa complanata*? Powis, and *Potamides fluviatile*.

* See Captain Harris's 2nd Report on the Mahanuddy. Sir E. Tennent's Ceylon, Vol. I.

† This is, however, dependant on the size of the lagoon and that of rivers passing into it.

It is probable therefore that were one of these lagoons elevated and thereby drained, the bottom would be found covered with a black mud without imbedded fossils, and much resembling regur in character. Near the estuary the deposit would be more sandy, and here possibly we might find a number of marine forms, intermingled with those washed down from the fresher parts of the lake.

We do not, however, need recourse to supposition to prove that regur is really the deposit of lagoons such as I have described. We have partly within the area of our map a striking case of one of these lagoons now nearly dry, or only flooded during the monsoons, the soil of which is a typical regur, and continuous with that which extends many miles into the country. From the Northern extremity of the Red Hill plateau (North of Pondicherry) a spit of sand, averaging a mile across, and in some places double, runs Northward as far as Mercanum. Within this spit, which is identical in formation with those which enclose most of the lagoons of the coast, a broad flat regur marsh extends inland 10 or 12 miles. The Southern part, that furthest from the estuary at Mercanum, is dry during a great part of the year, and covered with tufts of coarse grass (similar to that which grows on the higher plains of regur). Near Mercanum it is covered annually with salt water, when the floods from the small streams, which drain the inland country, have breached the sand spit; and salines are formed for the collection of salt on the reclosure of the spit. The Mercanum plain is therefore a silted up lagoon, and from the history of the harbours of the East Coast, all of which are similar lagoons or estuaries, it is evident that in the course of time all the former at least will eventually be filled in a similar manner.

There is no reason to believe that in the case of Mercanum the conversion of the lagoons into land has been aided by elevation, but from

the level of the actual plain the regur gradually ascends to much higher beds, and elevation must have operated slowly in raising these interior tracts above the level of the sea. The collateral evidences of upheaval are abundant along this coast. I have, in a previous part of this Memoir, described the escarpment which bounds the Red Hill plateau to the North of Pondicherry, and have given a drawing of that still finer example of an old marine escarpment which runs from the neigbourhood of Cuddalore up to the Madras and Trichinopoly road. Another equally fine in point of distinctness, but shorter, runs to the North of the Murdayaur, in Trichinopoly, and indeed in many other localities the little plateau of Cuddalore sandstones is bounded by escarpments more or less abrupt and elevated.

An instance of a somewhat older formation of regur than that of Mercanum is that of the lower valley of the Vellaur. On the left bank of this river, beyond the narrow fluviatile zone, the regur extends to some miles below Bhonagiri, (Bhuvanagiri) probably of considerable thickness. Between Bhonagiri and Porto Novo, three or four old spits* of sand run parallel to the coast, the innermost being not less than 6 miles from the present coast line. The regur in its typical form does not extend quite up to these, but becomes sandy and impregnated with salt and soda, which effloresce on the surface, but the deposit is continuous, its mineral character only being changed. To the North-east, near the Cuddalore river, beneath this sandy soda soil, a bed of shells occurs at a depth of 6 feet, and is worked by the natives in the neighbourhood of Kundyamelur for the manufacture of lime. The shells form about half of the mass of the bed, the matrix being a dark sandy mud, and they consist mainly of Cytherea casta, a common existing estuarine species, among which a few other species, more characteristically marine, are intermingled.

* This locality is of some historic interest as the scene of Sir Eyre Coote's victory over Hyder Ali—the battle of Porto Novo.

The following list of the species obtained from this bed is interesting, when compared with that which I give in a note,* of shells obtained by my brother from the estuary of the Chilka:—

Fragment of stag's horn.	Melania spinulosa (one specimen only).
Balanus sp.?	Rotella.
Murex tenuispinosa (fragment).	Ostrea. 3 sp.
Pyrula pugilina. Born. sp.	Anomia achæus. Gray.
Cancellaria.	Placuna ephippium.
Terebra.	Arca granosa. Linn.
Nassa complanata? Powis.	Cardita imbricata. Gmel. sp.
Nassa sp.?	Venus squamosa. Linn.
Purpura carinifera.	V. cor. Sow.
Oliva ispidula?	Cytherea casta. Gmelin.
Natica maculosa.	Cytherea meretrix. Linn.
Natica sp.?	Artemis amphidesmoides. Reeve.
Potamides fluviatile.	Tapes laterisulca. Lamk.
Potamides (Terebralia) telescopium.	Tellina.
	Sanguinolaria diphos.

From the above list of species, it is evident that the water in which the animals lived must have been strongly brackish, very few of the above are met with in existing lagoons, except in or near the estuary, and of characteristic fresh water mollusca only a single specimen *(Melania spinulosa)* was met with, this having probably been washed down from one of the feeding streams of the original estuary. The small size of

* The following species were obtained by my brother, Mr. William T. Blanford, from the estuary of the Chilka Lake:—

Balanus sp.?	Cytherea meretrix. Linn.
Nassa vittata. Adan.	Cytherea sp.?
Nassa complanata? Powis.	Venus sp.?
Potamides fluviatile.	Placuna placenta.
Potamides (Terebralia) telescopium.	Ostrea. sp.?
Cytherea casta. var. Gmelin.	

many of the shells, especially the Cytherea casta, and the distortion of the older specimens of Purpura carinifera, serve to prove on the other hand that some condition unfavorable to marine shells obtained, probably the occasional efflux of fresh water. We may conclude therefore from the geographical relations of the shell-bearing deposit to the old sand spits and the regur of the Vellaur valley, as well as from the character of the imbedded mollusca, that it was formed in the estuaries by which the lagoon once occupying the valley of the Vellaur communicated with the sea. The whole plain is now above the flood levels of the rivers, which cut through it, bounded by terraces.

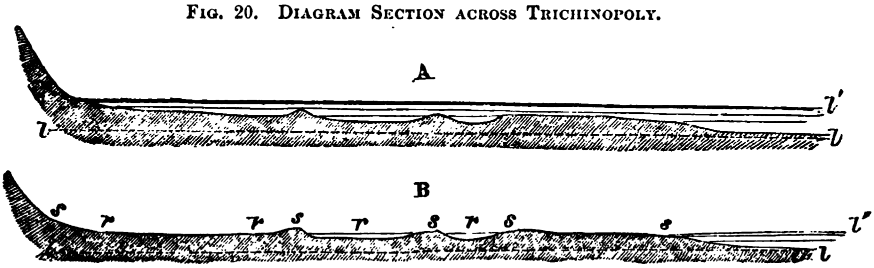
The above details are, I think, sufficient to convince us that lagoons similar to the Pulicat lake and the Chilka have existed at various levels now high above the sea, and that the regur of Trichinopoly and South Arcot is their peculiar deposit. I merely mention, before proceeding to the consideration of the origin of the red soil, that remains of mud spits less perfect than the above indeed, but otherwise resembling them, occur at more than one point near the actual edge of the Cauvery delta,* as at Trimulvassel and Carical.

The recent elevation of the plains and the lagoon origin of the regur being proved, that of the red sandy soil is readily suggested. It is a marine sand, such as accumulates (nowhere probably to any great thickness) on the sea shore at the present day. The great probability at all events of such an origin is seen when we remember its geographical relations to the regur as regards elevation, and consider what would be the condition of tracts slightly above the average level of the country during a course of slow upheaval. The accompanying figures (Fig. 20) are diagram sections across Trichinopoly from the

* These were mapped by Messrs. King and Foote, but I saw them myself subsequently and am therefore in a position to speak as to their real character from personal observation.

Patchamully hills to the Coleroon. The horizontal scale of the Section is $\frac{1}{12}$ inch to the mile. In *Fig. A* the whole tract is supposed to be

FIG. 20. DIAGRAM SECTION ACROSS TRICHINOPOLY.



l., actual sea level: *l.'*, *l.''*, hypothetical sea levels: *s.*, *s.*, areas of sandy soil; *r.*, *r.*, regur areas.

submerged beneath the sea, and the only deposit forming that of marine sand, such as covers the sea bottom near the shore of the present coast line, and is in all probability mainly derived from the sediment of the numerous rivers which debouch into the Bay of Bengal. In *Fig. B* the country is supposed to be elevated to such an extent that the high tracts *s. s. s.* are elevated above the sea level, while shallow water still covers the depressions *r. r. r.* These latter would now have much of the character of the existing lagoons, the outer tracts of elevated ground being analogous to sand spits, and indeed it is possible that in some cases spits may have partially closed the channels by which the depressed areas communicated with the sea. We should now have a mud deposit (regur) gradually formed in these, the formation ceasing only when either the lagoon was filled up, or when the whole area had been finally elevated above the sea level.

It will be readily seen how, in the state of things supposed above, the red sandy soil (sea sand) would descend on the sea-ward slope of a ridge to a much lower level than on the inner or lagoon-ward slope, as in the case illustrated in Fig. 19, page 189. In this case, during slow elevation, the surf would continue to break on the Southern slope of the ridge long after the regur deposit on its Northern slope had been formed, and even partly elevated above

the sea, and regur would only be deposited to the South of the ridge when either continued upheaval had raised another and outer ridge above the sea level, or a sand spit had been formed, converting the lower area in its turn into a lagoon.

There is, however, one fact which presents itself as a difficulty to the above hypothesis; *viz.*, that, supposing the country to be covered in the first instance with the sandy soil even on those areas which are subsequently covered with regur, we should expect *à priori* to find, in most cases at least, a deposit of the former underlying the latter, but this I have only observed in a single case. I can only suggest to account for this that seeing the small average thickness of the red soil, and remembering that there is frequently evidence of the material of underlying rocks when soft being washed up into the lower part of the regur, that the original deposit of sand has been in like manner intermixed with the subsequently formed regur, possibly by the movement of the water over the shallow bottom of the lagoon during the ebb and flow of the tides. Regur always contains a large proportion of sand, and the usual characteristic red color of the sandy soil (due to the peroxidation of the magnetic iron it originally contained) would be obscured by the coloring matter of the regur, even supposing the peroxidation of the iron had not been checked by the presence of organic matter in the latter soil. The single instance in which I noticed regur resting on the sandy soil was to the South-west of Chellumbrum, where the underlying rock is in all probability Cuddalore sandstone. I have previously noticed the prevalent greater thickness of sandy soil on this group of sandstones, and I infer therefore that in this case the deposit of the red soil was originally too thick to be washed up into the regur, as occurred in the case of thinner deposits.

It now remains to show that the chemical composition of sandy soils is such as we may reasonably expect them to have been formed from the shore sand.

The following is an analysis by Mr. Tween of a specimen of red soil from Puttoocautaincoodicaud, a few miles South of Wodiarpolliam. The specimen was taken from about 4 feet below the surface:—

Silica		64·3	Insoluble in acid.
Alumina	22,48	19·2	Insoluble in acid.
„	22,48	3·28	Soluble.
Peroxide of Iron		5·4	Soluble.
Water and organic matter		7·	Soluble.
Residue, traces of Magnesia, Lime, Alkali, Sulphuric Acid and Chlorine		0·82	Soluble.
		100.00	

A specimen of shore sand from Cauverypatam, also analysed by Mr. Tween, gave at least 75·00 per cent. of silica, about 12 per cent. of oxide of iron, and 8 of alumina; a little lime, manganese, magnesia and soda being also present, with sulphur (in sulphuret of iron) and chlorine.

It appears from the above that the soil contains a smaller proportion of silica than the sand of the sea coast, and more alumina or clay, but the former was taken from a depth of 4 feet, and the sand from the surface, where any argillaceous matter would have been washed out by the waves. Had the sand been taken from 2 or 3 feet below the surface, it would probably have contained a larger percentage of alumina judging from the muddiness of water penetrating at that depth when a hole is made in the sand.

In the above analysis the percentage of iron is larger in the sand than in the soil, but this varies considerably in other specimens of both, as will be seen from the following estimations by Mr. Tween:—

	Iron.		$Fe_2\,O_3$
Rich specimen of shore sand from Cauverypatam,	33·2	=	46·6
Average specimen same locality	8·8	=	12·5
Specimen from Tranquebar	9·7	=	17·5
Specimen from Negapatam	1·7	=	2·4

Red soil from Puttoocautaincoodicaud, 4 feet below surface	3·78	=	5·4
From same locality at 6 feet below surface (with pisiform concretions)...	9·00	=	12·8
From Punrùtti in S. Arcot	1·46	=	2·0
From Munnagoody in Trichinopoly...	2·1	=	3·0

It should be remarked that the specimens poorest in iron, both of the sand and the soil, are more strictly average specimens, or in other words, sand and soil, containing those percentages of iron, are far more common than those with 7 or 8 per cent. The sands of Cauverypatam and Tranquebar are exceptionally rich and rare; the iron peroxidised and the soil submitted for a long period to atmospheric action would probably form laterite, which rock has a percentage of iron varying from 12 to 30 per cent. and upwards.

The iron exists in the shore sand in the form of magnetic iron, and is derived originally from the Crystalline rocks. I have already noticed in the foregoing Memoir on the Cretaceous rocks, that there is scarcely a nullah in the country in the sand of which magnetic iron does not exist, whether it drain crystalline or sedimentary rocks, but it is more abundant in those derived immediately from the former.

It is probable that the magnetic iron is always most abundant along the intertidal zone of the strand, and that its proportion diminishes with the depth of the sea. The sand in this zone is under conditions similar to those of metallic ore on a frame or percussion buddle, being on an incline (usually steep in the case of the Madras Coast) and submitted to perennial washing by the waves. But during the slow elevation of the country each and every part of the ridges now occupied by red soil must have been in its time subject to the above conditions immediately previous to its final conversion into dry land, and I would thus explain the prevalence over the country generally of

soils or superficial deposits (including laterite*) rich in iron, richer as a rule than thick sedimentary formations originally derived from the same source, *viz.*, the metamorphic rocks.

The foregoing remarks on the origin of the regur and sandy soils of Trichinopoly are probably applicable to those of a large part of the Peninsula, but I, for the present, confine myself to the considerations of those which I have personally observed; the elevation of the Indian Peninsula, evidenced by their extensive occurrence at considerable elevations is a phenomenon of great importance which should be considered in connection with some other facts, the treatment of which is beyond the scope of the present paper.

* I do not here mean to assert that all laterite is thus formed. Any deposit rich in iron may form a laterite when exposed to the action of the atmosphere, and in Southern Ceylon gneiss decomposed *in situ* assumes a lateritic structure.

PART III.—ECONOMIC GEOLOGY.

Mineral produce but little utilized.

THE Trichinopoly and South Arcot districts are comparatively rich in minerals valuable in the arts, although but few of them have hitherto been utilized, and those few chiefly by the natives, whose selection is directed more by the consideration of what is easily worked with their rude appliances, than what is calculated to yield the most valuable forms of manufacture by more perfect processes.

Inaptitude of the district for active manufacture.

Owing to the want of fuel, either vegetable or mineral, these districts are unfortunately not fitted to become the seat of any great manufacturing activity, and thus many of the more widely spread, and, under other circumstances, valuable minerals, such as iron ores, are unlikely ever to be utilized to any extent; while, owing to the want of cheap transport, the poverty of the people of Southern India, and the absence of manufacturing skill, it may be long before other minerals of more value, such as fine clays, limestones, &c., will become generally available for the purposes of the arts. Still, even in late years, much progress had been made in removing the first of these obstructions, by the formation of several good roads, and especially of the railway from Trichinopoly to Negapatam, which will afford egress to the coast, and introduce at the same time the seeds of a higher material civilization, which, in process of time, fostered by the political improvements now in progress, cannot fail to produce its fruit in the improved condition of the people, and eventually in creating a demand for luxuries and conveniences now totally unknown.

Means of transport.

Although, therefore, it is not to be anticipated that a record of the Economic Geology of the districts surveyed may lead to any immediate results of importance, it may be useful at some future period, in directing attention to their mineral capabilities, such as they are, and may be the means of saving much time and expense in the institution of special mineral surveys, when the increased wealth of the country shall have created a demand for raw materials now comparatively worthless.

The chief minerals of economic value met with in the course of the Survey are as follows :—

Building Stones, Stones for Road-metalling, &c., including Gneiss, Green-stone, Crystalline and sedimentary limestones, Sandstone and Laterite.

Limes and Cement Materials ; comprising Crystalline limestone, Coral reef and other sedimentary Limestones, Septaria, Kunkur and Fossil Shells.

Brick Clays.

Fine Clays and Pottery materials, *viz.* : Pipe Clays and Ferruginous Clays, Kaolin and China Stone, Felspar and Flints.

Gypsum.

Common Salt and Soda.

Iron Ores.

Copper Ores :—only in very small quantity.

Ornamental Stones, *viz.* : Shell and other Marbles, Rock Crystals. Cairngorums, Jasper.

With regard to many of the above, such as certain of the limes and clays, it is difficult to pronounce upon their value. A few only are used by the natives, or by the Officers of the Public Works, and experiments would be necessary to determine how far the other materials are applicable to various purposes.

Building-Stones, Road-metalling, &c. Of the various stones I have enumerated, all perhaps are used more or less for building, and for the manufacture of rice, or paddy mortars,* water troughs, and similar household utensils. The only buildings, properly so called, for which stone is employed by the natives, are the lower portions of the large native temples, for which gneiss alone is used, whatever be their situation; and the small village *kovils* and *chuttrums* (or native rest houses,) which are constructed usually of the stone nearest at hand; on the Cretaceous rocks generally of some form of limestone. A large quantity of roughly hewn stone is also employed by the natives for revetting the inner slope of the larger tank bunds, and for constructing the *kalingulas*, or waste-water channels, as well as for walling the large rectangular irrigation wells or *bowries* (when sunk in loose ground). Rough stone-causeways are also met with in some villages for the purpose of affording a dry footway, when, after heavy rain, the usual roads are cut up into an almost impassable morass by the passage of carts and the flocks of buffaloes, cattle, goats, and sheep, which form the chief wealth of the agricultural population.

Employment of building stone by natives.

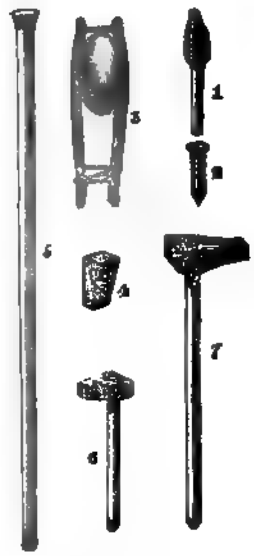
The method of quarrying employed by the natives is the same, whatever be the nature of the stone. Gunpowder is never used except in quarries opened by Europeans, as *e. g.* those lately worked in the gneiss at Penmullay, near Trichinopoly, for the supply of the Railway works. The stone is detached by large iron wedges driven by a heavy stone mallet, (*see* Fig. 21,) into a line of holes previously cut with the gavel and chisel; and the block then raised by a crowbar, due advantage being taken of the planes of bedding or jointing. By this means blocks of 5 or 6

Native method of quarrying.

* The mortars in which rice, or paddy, is pounded in order to free it from the husk. In Southern India a wooden or stone mortar is used for this purpose, the pestle being a pole about 5 feet in length, shod with iron.

feet in length, and 2 or 3 feet in width and thickness, are obtained with the expenditure of a considerable amount of labor, and if requisite, are afterwards roughly trimmed with hammers on the spot, and then transported to the required locality on rude buffalo carts. Regular excavations are rarely opened for quarrying purposes. In general the stone is obtained from some rocky ridge, the soil being previously sounded with a crowbar to ascertain the existence of a block at no great depth, the stone is uncovered and detached, and the hole abandoned, to be filled with rain and mud on the first heavy downpour. Thus the outcrop of a band of limestone may be frequently traced by the row of little pits, left by the native quarrymen; although no rock is perceptible at the surface.

FIG. 21. QUARRYING TOOLS.



1, Gavel. 2, Chisel. 3, Stone mallet. 4, Iron wedge. 5, Crowbar. 6, 7, Trimming hammers.—

Gneiss and Trap.

Gneiss and trap are the most durable stones obtainable for those parts of buildings that are exposed to the weather. The latter is but little used, as it occurs only in a few dykes in the neighbourhood of Ootatoor and Volcondahpuram, and owing to its extreme toughness, is only obtainable with great labour by the native method of working. Judging from the almost inappreciable extent to which exposed blocks of this stone have been affected by the weather, it must claim pre-eminence, in point of durability, over all other materials except perhaps some of the Quartzo-felspathic varieties of the gneiss, the permanence of which is attested by the great rounded tors and bossy hills of this rock scattered over the country, and also by the delicate carvings of some of the pagodas, notably those at Tanjore,

which have existed at least for one or two centuries, and although exposed to the ultimate action of the heat and heavy periodical rains, exhibit in many cases the marks of the chisel and the delicate sharpness of ornament, almost as clearly as when turned out from the sculptor's hand. Gneiss of this kind prevails to the South of the Cauvery, and also occurs in the northern part of the Trichinopoly district, and in South Arcot; but in a few spots only, where its presence is indicated by a projecting boss or hillock, most of the gneiss in this part of the country being decomposed to the depth of many feet beneath the even-covering of soil. It is usually of a pale grey fracture, and shows but little trace of foliation.

As road-metalling.

Gneiss is used to some extent for metalling the Trichinopoly Trunk Road, chiefly in the immediate neighbourhood of Trichinopoly. Elsewhere the decomposed rock is employed, much of which is little better than a friable sandy gravel, except where the ferruginous sub-lateritic form of the same material is obtainable, a metalling which binds well but is scarcely hard enough to stand the great wear and tear to which this road is subject. The anamesite (?) of the dykes which cross the road at several places in the Trichinopoly district, has never been employed, so far as I have observed. It would undoubtedly be the most lasting material procurable, the only question being, how far the increased expense of quarrying and breaking up would be met by its greater durability.

Crystalline limestone.

The only spot at which I have met with crystalline limestone, within the limits of my own survey, is in the middle of the granitic ridge of Thutchuncoorchy, about two miles to the North-east of Cullpolliam, a village on the Madras road. It was not worked at this spot, but several bands of a similar rock have been noticed by Messrs. King and Foote to the Westward, where they are quarried by the natives for building purposes. The stone is too soft and pure to withstand the solvent action of rain for any great time.

Cretaceous limestones.

The same remark will apply to most of the limestones of the Cretaceous rocks, which are, however, quarried to a considerable extent, for the construction of small village *pagodas* and *chuttrums*. The chief locality from which stone for this purpose is procured, is the ridge at the base of the Ootatoor group, which extends from Purawoy to Vylapaudy; much is also obtained from the ridges of coral-reef and sedimentary limestones, similarly situated, at Assoor, Maravuttoor, Cullpaudy, Sirgumpoor, Varagapaudy, and many other places further to the Southward. The ridge of shell limestone between Garoodamungalum and Alundanapuram, is another favorite locality, and indeed wherever a band of limestone or calcareous grit crops out heaps of fragments and lines of wedge holes show that the spot is occasionally resorted to by the native quarrymen.

These limestones are of various degrees of purity. Specimens of the coral-reef limestones, analysed by Mr. Tween, gave from 95 to 98 per cent. of carbonate of lime. The Olapaudy limestone, above mentioned, is somewhat less pure, and some of the calcareous grits, such as those in the upper part of the Ootatoor group, between Kolokaunuttom and Shutanure, do not contain probably more than 20 per cent. of calcareous matter. The coral reef and purer sedimentary limestones have been fully described above (page 52). They are tolerably compact, but as may be seen in the coping stones and drip stones, and the exposed mouldings of kovils, built of these rocks, they are but ill qualified for exposed exteriors, where they rapidly yield to the heavy tropical rains. These stones being soft, and easily worked, are used to a considerable extent by the natives of the district for rice-mortars and water troughs.

Sandstones.

The sandstones of the Cuddalore group are quarried to a small extent at Velur, near Verdachellum, and at Vellumpaleyam, on the bank of the Guddalum. The stone is compact, moderately fine in grain, and being jointed in two

directions, is easily quarried. It is worked for the household purposes above-mentioned, and is also used to some extent for dry walling. The mile-stones on the roads about Verdachellum are also made of this stone. It appears to be well adapted for building, but I am not aware that it has ever been employed for this purpose.

Laterite.

Laterite is largely used for building wherever it occurs. Its chief localities are at Vullam in Tanjore, and Strimustrum, in the North-east of Trichinopoly. I have also noticed it at several places between Tanjore and Trichinopoly, and at Andanapet, to the East of Verdachellum, and it probably covers a great part of the Cuddalore sandstones concealed beneath the red soil. At Vullam it is cut with a chisel-pointed crowbar, into blocks 2 feet 6 inches long, 1 foot wide, and 6 inches thick. It is, when first extracted, a flaky ferruginous sandy clay, and rather friable, but when exposed for some months to the action of the rain and sun, as is usually the case before it is used for building, it hardens and becomes covered with a dark polished encrustation of hydrated oxide of iron, which protects it from further change, and resists the decay of the stone, however long it may be exposed. At Vullam it is much used by the natives, in building their houses, in preference to brick, and the Vellaur annicut at Chetia-tope, near Bhonagiri, is built in part of this rock quarried at Strimustrum.*

As road-metalling.

Laterite, as is well known in India, makes an excellent road-metalling when not required to stand the wear and tear of heavy traffic. A lateritic gravel is much used for this purpose, when the solid laterite is not procurable, as on the Madras and Trichinopoly road, between the Vellaur and the Puniar, and on the Madras and Pondicherry road to the North of the latter place. In the former case, it is obtained from pits near Anawari, to the South of the

* At Andanapet I noticed some carved blocks forming part of an old and ruined pagoda, the mouldings of which were as perfect as when first cut. Owing to its porous structure, however, Laterite is but little fitted for fine sculpture.

Guddalum, in the latter from the Red Hills, over which the road passes for some miles.

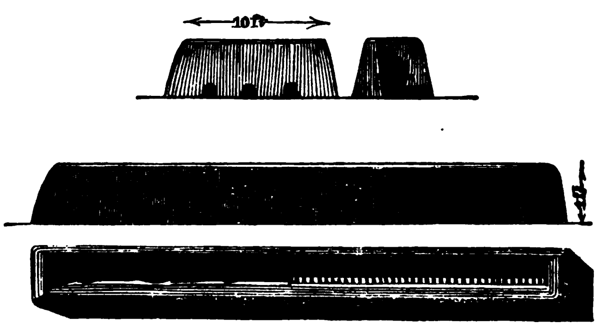
Materials used by natives.

Limes and Cement materials. Of the various materials available for the manufacture of lime, two only are used, *viz.*, kunkur and shells. The former occurs abundantly over a great part of the area described, both on the crystalline and sedimentary rocks, and to some extent in the fluviatile alluvium of Tanjore and South Arcot. The latter is used on the Coast, and at those spots at which shells are found in sufficient abundance in a fossil state; chiefly at Kundyamalur, a few miles to the West of Porto Novo.

Native process of lime burning.

The intermittent process of burning is the only one practised, and the quantity of lime burnt at one operation is usually small, frequently less than a hundred weight. The kilns are of mud, and vary in construction: in South Arcot they are

FIG. 22. NATIVE LIME-KILNS IN SOUTH ARCOT.

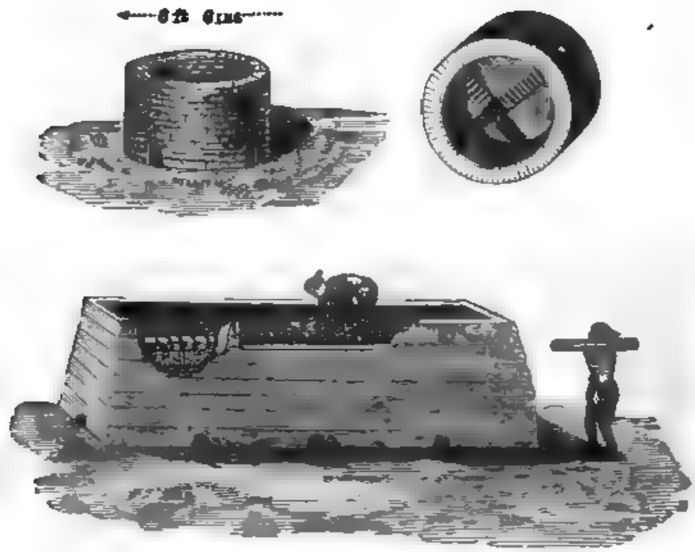


usually trough shaped, and furnished with bars either of thick sticks, or bricks and potsherds built into the walls, at about 18 inches from the ground (*see* Fig. 22). On these the kunkur, (in fragments of the size of a walnut or less,) or shells are piled, mixed with the fuel, which consists of wood, charcoal, or where the Palmyra is abundant, of the dead leaves of that palm; and the mass being ignited from below, is allowed to burn out, fresh fuel and material being piled on the top, as the charge sinks, until the kiln is full of quick lime. This is allowed to cool and is then

removed. In South Arcot lime prepared in this way is sold (1861) at the rate of 2 annas (3*d.*) a basket full, an amount which I estimated at about 15 lbs.

In Trichinopoly and Tanjore a larger kiln is used, two forms of which are represented in the annexed figures. A layer of bricks laid at the bottom, leaving interspaces communicating with the air holes, replace the bars of the smaller kilns of South Arcot. In the large rectangular kiln represented, the kunkur was laid in layers, alternating with large billets

FIG. 23. NATIVE LIME-KILNS IN TANJORE AND TRICHINOPOLY.



of wood. In other respects the process was as in the former case, and when finished, the kiln was broken down for the extraction of the lime.

The mortar prepared from kunkur is very hard and lasting. In the bed of the Vellaur river at Shoundrasholaspuram I noticed some large masses of brick-work, the remains apparently of an old dam, in which the mortar had been worn by the united solvent and frictional action of the water, much less than the imbedded bricks by the latter action alone. Mortar appears, however to be used sparingly in all stone edifices. In some of the large pagodas

Durability of kunkur mortar.

the stones are either laid together without mortar, or so little is used that it is not seen at the surface of the work. A large tank (now dry) at Naicolum, a few miles to the South of Ootatoor, is walled with beautifully cut blocks of gneiss, which appear to be built together entirely without the aid of any cement, and the same remark is applicable to many of the *chuttrums* and the *mundapums*, the roofs being constructed of long blocks of gneiss, carried on joists of the same rock, which in their turn are borne on the elongated capitals of the square columns, all, so far as can be seen, laid dry without mortar. One of the finest examples of such structure I met with is an old mundapum at Vungadumpett, a small village between Verdachellum and Cuddalore.

I have already pointed out some of the chief localities at which crystalline and sedimentary limestones are procurable, and a reference to the body of the report will give many others in the case of the latter rock. There is another form in which lime occurs in the Cretaceous rocks, to which I have not yet alluded, and which may be noticed as promising a valuable material for certain specific purposes, though as yet untested; I refer to the calcareous nodules, which are very abundant in certain beds of the Ootatoor and Trichinopoly formations, and which, so far as can be judged without actual trial, are probably well adapted for the manufacture of hydraulic cements. The chief localities at which these are procurable are: in the gypseous clays to the East of Ootatoor, in which nodules, from the size of a marble to that of a small melon, occur in vast numbers, and may be had for little more than the expense of carriage. Concretions of a somewhat similar character occur in a sandy clay in the upper part of the Ootatoor group, near Coonum; frequently enclosing fine specimens of Nautilus. The bed containing them is exposed in the broken ground to the West of the village, and also in the nullah draining the ridge between that place and Moonglepaudy. The nullah to

Septaria and calcareous nodules.

the North of Anapaudy exposes a bed of similar concretions in the lower part of the Trichinopoly group; the matrix being, as in the former case, a fine sandy clay.

Kunkur.

The best and purest kunkur I have noticed occurs in great abundance in the laminated sandy clays of the Trichinopoly group, to the West of Cullygoody; and large quantities may be collected in the nullahs and broken ground between that place and Thapaye; a place to which the natives of the surrounding villages are accustomed to resort for this material. Kunkur, perhaps equally good, is found in similar beds of the Ootatoor group to the East of Terany and Kauray, and the mineral occurs more or less throughout the gypseous clays to the East of Ootatoor, and to the South and South-east of the same place. On the Arrialoor beds in the East of the district, it usually forms a bed of one or two feet in thickness, being probably derived in a great measure from the denuded beds of the group; and a similar bed frequently occurs in the same position on the surface of the gneiss, where this rock is covered with regur. In the old alluvium of the Vellaur and the other large rivers, kunkur always occurs to some extent, but it is less abundant in the more recent deposits of the Cauvery delta. It is probably in a great measure owing to the almost universal distribution of this mineral, and the ease with which it is collected, as much as to its excellence as a material for mortar, that the limestones so abundant throughout the district have been hitherto almost entirely neglected as a source of lime.

Shells.

On the sea shore, the broken shells thrown up by the waves, are collected to some extent for the manufacture of lime; and in large stations near the coast this material is employed to a considerable extent in the manufacture of the pure white marble-like stuccoes used for verandahs and interiors. At Kundyamellur, near Porto Novo, a bed of sub-recent fossil-shells, (chiefly a variety of *Cytherea castanea,*) is excavated for the same

purpose, the shells being washed previous to burning. Similar deposits occur at Pondicherry, and also at the Adyar, a few miles from Madras.

Brick Clays. The only clays used by natives for brick-making, are those of the fluviatile alluvial deposits, and more rarely of the superficial deposits, which cover the gneiss of the low country. The latter are in general but little adapted for the purpose, consisting either of a sand, with too small a proportion of clay, or of regur which, on the other hand, is an almost pure loam. Where the two forms of soil meet and intermingle, are the best spots for the purpose of brick manufacture. It is only in towns and some few large villages that bricks are much used, the huts of the agricultural classes being, as is usually the case throughout India, built of mud with thatched roofs. The native process of brick-making is a rude form of that commonly practised in more civilized countries. The clay, which is always so sandy, as to enable the workmen to dispense with the preliminary process of pugging, is mixed by the aid of a shovel, with sufficient water to render it a semi-fluid paste, which is rudely and rapidly moulded in a wetted mould, and the bricks, being dried in the sun, are burnt in a kiln in the usual manner.

Alluvial clays used by natives.

The native bricks are soft and bad, frequently containing cavities, and irregular in shape, but this is due to want of proper care in mixing and moulding and to insufficient burning. It is probable that the same clays used by them would yield excellent bricks under an improved process.

Fine clays and pottery materials. The Cretaceous rocks and plant beds of Trichinopoly yield several fine clays well adapted for the manufacture of pottery; and other materials used in the ceramic arts, *viz.*, China stone and kaolin, felspar, flints, and gypsum, are all obtainable within the area described in the foregoing report. None of these are

Pottery materials available.

utilized by the natives, whose pottery (unglazed and porous,) is made chiefly from sandy ferruginous clays, which occur at one or two places in the superficial deposits. I have met with this latter overlying the plant beds between Terany and Kauray, close to the old Trichinopoly road, and also covering the Cretaceous rocks on the slope of the high ground to the South-east of Vemmany (North of Arrialoor). At both these places it is collected by the native potters of the adjoining villages. The former is a very ferruginous plastic clay, the latter less ferruginous and sandy, but sufficiently plastic to work on the wheel, without difficulty, when well kneaded. Either would answer well for brick-making, or the manufacture of common red pottery. The Vemmany clay is a somewhat argillaceous form of the common red soil of the country, and probably an equally good material might be obtained from several parts of Wodiarpolliam, where this soil predominates.

Chatty (native pot) clay.

A fine pipe clay occurs in the plant beds between Terany and Kauray, forming a thick bed which is exposed in one of the small feeders of the Terany tank, about a mile and a half to the North-east of the village. The clay is a greyish white clunch, with a few stains of iron, but were a pure clay required, the stained parts might be easily separated by hand picking. This clay, when ground and kneaded, works well, and when burnt assumes a blueish white tinge.

Pipe clay.

Another fine clay, somewhat more sandy than the above, but highly plastic, is that which underlies the Reptilian bone beds to the East of Ootacoil and Coothoor (North-east of Arrialoor). One or two thick beds (containing casts of small fossils) are exposed in the nullahs to the North-east of the latter village. This clay is of a greenish grey tint, and occurs broken up into small angular fragments. It requires grinding for use, but is very plastic, and when burnt assumes a pale reddish-brown tint, owing to a small proportion of iron.

Fine ferruginous clay.

In the South Arcot district, a fine plastic clay occurs in the Cuddalore beds near the South bank of the Guddalum, opposite to Punrùtti, and is exposed by the side of the road leading Southward from that place. It contains a small quantity of iron and lime, and owing to the former, has a pale flesh tint, which becomes darker on burning. It is soft and extremely tenacious.

Cornish stone and kaolin.

Cornish stone, from which a somewhat ferruginous kaolin may be obtained by washing, occurs at Semangalum, close to the borders of the Cretaceous and Cuddalore rocks 6 miles North of Valudayur (near Pondicherry). It is only seen in a well to the West of the village, the debris from which consists entirely of the material in question. The well is about 20 feet across. It is impossible to say how far the rock extends beyond, as nothing is seen *in situ* anywhere around. It is probably a broad vein of Pegmatite running through the gneiss, such as are frequently met with in the surrounding country.

Felspar.

The granitic ridge to the North of the Cauvery contains a large quantity of felspar, and this mineral might be easily obtained free from any admixture of quartz. Large quantities are scattered over the stony parts of the ridge, and might be collected at small cost. It is apparently an orthoclase, but it has not yet been analysed.

Flints.

Flints, almost undistinguishable from fragments of English chalk flints, are found at Coorchycolum, a village in the North-east of the Trichinopoly district, a few miles South of the Vellaur. They occur in the highest part (exposed) of the Cretaceous rocks, near the overlap of the Cuddalore beds, and probably form a continuous band running North and South; as I found similar flints to the South-east of Sainthoray, at a place the bearing of which from Coorchycolum is about that of the local strike of the bedding. The country is, however, too thickly covered with soil to admit of the flint

bed being traced in the interval. These flints are used by the natives of the surrounding villages for obtaining fire with a steel. They are not well seen *in situ*, but as I have never met with anything like a concretionary nodule, such as occur in the chalk of Europe, but only irregular fragments, I am inclined to believe that they form a continuous band now more or less shattered.

Ochre.

I have mentioned before the occurrence at Trivandipuram of yellow ochre, which is used by the natives for making their caste marks. When ground and lævigated, it yields a very good pigment. The chatty clay of Terany treated in the same way yields a deep red pigment.

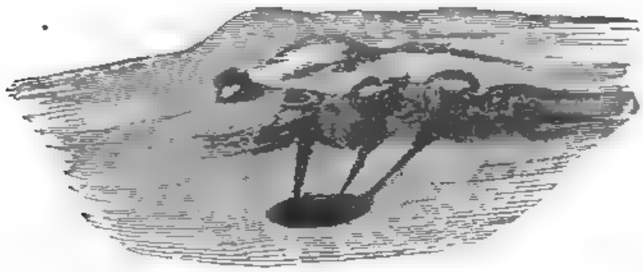
Gypsum.

Gypsum. This mineral is common in many parts of the Cretaceous rocks of Trichinopoly; generally in the form of fibrous plates intercalated in the bedding, and of no great thickness: more rarely in concretions, and replacing the shells of Nautili, Ammonites, and other fossils. I have nowhere seen a pure gypsum fitted for the preparation of stucco or statuary casts, as it almost invariably contains a small proportion of clay, which cannot be separated by washing, and which would destroy its whiteness; but it may be obtained, in any desired quantity, of sufficient purity for the preparation of moulds, such as are used in the ceramic arts, or indeed for any purpose in which pure whiteness is not essential. It is most abundant in the Ootatoor beds, especially in the Belemnite clays to the East of Ootatoor, and in the unfossiliferous clay to the North-east of Maravuttoor. At the former place it occurs in fibrous plates of from half an inch to 2 or 3 inches in thickness, and may be collected in any quantity in the broken ground between Ootatoor and Garoodamungalum. At Maravuttoor it occurs both in the fibrous form, and in transparent plates, (Selenite) and crystals irregularly intercalated in the clays of the lower part of the group. Fragments of great purity may be easily selected, but it cannot be obtained in any quantity free from the argillaceous matrix.

Salt and Soda. Common salt effloresces from the soil and superficial rocks over a considerable area to the North of Lalgoody, in the Trichinopoly district; and is collected by the poorest of the village people for household use. It is very impure, containing apparently a considerable admixture of chloride of calcium, which gives it a disagreeable bitter taste, and which the village people have not the art of separating. It is chiefly collected from the beds of nullahs, where, after a drought of a few weeks, it covers the sand with a thin efflorescence. The surface sand is scraped together by the villagers, lixiviated in some such arrangement as that shown in the annexed sketch (Fig. 24.), and the solution thus obtained, evaporated to dryness in

Common Salt.

FIG. 24. NATIVE METHOD OF LIXIVIATING SALT-EARTH. TRICHINOPOLY.



the sun, on flat stones, round which a rim of clay has been made to retain the solution.

Soda is of wide spread occurrence in the South Arcot and Trichinopoly districts, chiefly on the gneiss, and on the alluvium, more rarely * on the Cretaceous rocks. It occurs in a whitish soil, known as "Soud" or "Dhobee's earth," usually occurring in marshy places, and very treacherous to the unwary pedestrian. A large extent of it occurs between Trichinopoly and Tanjore, to the South of the Cauvery; and the alluvial plain to the North of the Vellaur, in the neighbourhood of Chetia-tope and Bhonagiri, is formed in

Soda.

* Never *derived from* the Cretaceous Rocks, but from the decomposition of the many varieties of hornblendic and felspathic gneiss. T. OLDHAM.

great part of a similar soil; small patches of "Soud" are also frequently met with on the gneiss, to the West of the Cretaceous rocks in South Arcot, chiefly where the prevailing soil is regur. The earth is collected by washermen and used instead of soap for washing cloth. The soda is frequently mixed with common salt, and probably with other soluble salts, but it has not been analysed.

Iron Ores. The cretaceous rocks contain in several places ferruginous nodules, which mounds of old slags prove to have been worked by the natives at some former period. The greater part of the plains is now too denuded of jungle to allow of fuel being consumed in the production of iron, however abundant its ores may be, and no iron has been made in either Trichinopoly or South Arcot (so far as I could learn from frequent interrogations,) within the memory or even the traditional knowledge of the existing generation. All iron used by the natives of these districts is obtained from Salem, where the neighbouring hills still yield wood, for smelting the rich magnetic ores so abundant in that district.

Cretaceous rocks formerly used.

Ferruginous concretions, which have been at one time worked by the natives, occur in the Ootatoor beds to the South of Ootatoor, and in the lower beds of the Arrialoor group, to the South of Arrialoor: also in higher beds of the same group near Thaloor fragments of rich iron ores occur, covering the ground, and bedded in the ferruginous soil, near Kondamungalum (page 138), being derived, in part at least, from the ferruginous beds of the Cuddalore group.

Localities.

The iron ores used at the Porto Novo Iron Works were the magnetic ores of Salem district.

Copper Ores. The gneiss in the neighbourhood of Olapaudy and Vapoor (in the North of Trichinopoly,) shows frequent stains of copper, and in a small nullah, to the South of the latter place, I found two or three pieces of cupriferous veinstone,

At Vapoor.

but was unable to discover their origin. The specimens were considerably waterworn, they consisted of quartz with little nests of malachite, red oxide, fahl-erz and native copper, and were of sufficient richness to repay working, were there any quantity of ore equally good. The gneiss around is much penetrated by little cracks filled with quartz and calc-spar, and it is probable that the veinstone had been derived from one of these, of unusually large dimensions.

Shell marble of Garoodamungalum.

Ornamental Stones, &c. Under this head may be included the marbles which I have already described under the head of limestones; and a few varieties of quartz of no great importance, but some of which are worked to a small extent by the native lapidaries at Vullam, in Tanjore. The only marble worked by the natives as such, is the shell marble of Garoodamungalum, of which table-tops, paper-weights, and similar ornaments are manufactured in Trichinopoly. When polished it is of dark-grey color, and is marked, like the well known Purbeck stone, with white sections of the included shells.

Jasper of two varieties, the one a yellow and red stone, the other a cream-colored porcelain jasper, occur in the Cretaceous rocks; the former near Olapaudy, in the bottom beds of the Ootatoor group, the latter in the Trichinopoly group between Thaloor and Cullygoody. Pebbles of rock crystal and smoky quartz, (Cairngorum,) are found in the Cuddalore conglomerates at Vullam, and are cut by the natives of the place into spectacle-lenses and also as jewels. Amethysts also are frequently sold by the lapidaries here, but I found on enquiry that they are all brought from Kungyam, in Coimbatoor.

APPENDIX.

List of Trichinopoly species given in Professor Edward Forbes's Memoir, Geological Society's Transactions, Vol. VII.

Those marked with an * were erroneously referred to Verdachellum.
Those marked with an † occur both in the Trichinopoly and Arrialoor groups.
Those marked *Forbes*, are given on the authority of Professor Forbes's Memoir, as I have not yet identified them.

* Ammonites Gautama.
† Ammonites sugata.
* Pleurotomaria Verdachellensis ?
Nerita compacta.
† Turritella monilifera.
Turritella Sowerbiï.
* Chemnitzia undosa.
Cerithium Trichinopolitense. *Forbes.*
Murex Trichinopolitensis. *Forbes.*
Pyrula cancellata.
Strombus contortus.
Voluta Trichinopolitensis.
Tornatella semen. *Forbes.*
Ringicula (?) acuta. *Forbes.*
Natica suturalis.
Dentalium hamatum.
Poromya lata. *Forbes.*
Psammobia inconspicua. *Forbes.*
Mactra tripartita.
Astarte planissima.
Cardium interruptum.
Cardium altum.
† Cardium Hillanum.
Venus Arcotensis.
Venus analoga.
Venus eximia.
*† Artemis lenticularis.
*† Arca abrupta.
*† Arca Trichinopolitensis.
* Modiola typica.
Pecten virgatus. *Forbes.*
Ostrea amorpha. *Forbes.*

H. F. BLANFORD.

Note on Chapter XII.

In this Chapter (XII.) Mr. Blanford has very fully entered on the discussion of the character and distribution of the recent deposits of the districts he has visited. These views I do not desire at the present, either to support with additional evidence, or to gainsay, although there is much which might be urged, but I think it just to others who have also examined these districts, to state that in many respects their views differ from those of Mr. Blanford. Omitting any question of how far the term 'soil' may be justly applicable to many of the deposits described above, my own examination of a large part of these districts and the investigations of others in the same and other portions, lead us to think that very much larger areas than are spoken of above, are covered with soils (?) or deposits which are solely the results of the local decomposition of the underlying rocks. This appears unquestionably the case with a very large part of the Cuddalore sandstone country.

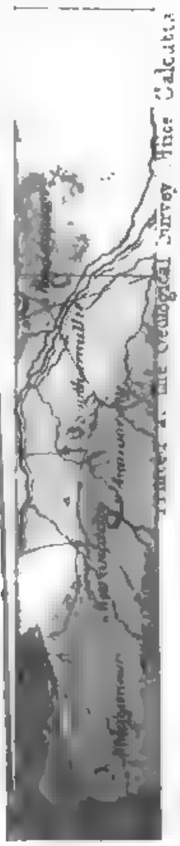
The non-fertile character of what is called 'regur' in Trichinopoly is noticed. I would here desire to express a caution against the very lax use of this term 'regur' or 'cotton soil,' which applies it indiscriminately to all clays which have even a tendency to a blackish colour. Clays varying in the amount of their organic matter from 1 per cent. to 12 or 14 per cent.; in the amount of their lime from 2 to 17 per cent.; in their colour from a deep black to a sandy grey, and in their texture from a fine and strongly adhesive clay to an earthy sand, have been all set down as 'cotton soil' or 'regur,' although their origin *must* have been different, and their agricultural capabilities essentially distinct.

There is, too, as it seems to me, too hasty and too locally based, a generalization, in stating that this 'regur' occurs always in the lower portion (relatively) of any given part of the country. In many cases where I have noticed that it does occur in these relative depressions, the fact appears simply due to the washing off of the previously existing thin coat of regur from the higher ridges, by the ordinary *pluvial* action of the country: thus exposing the red soil beneath. This red soil is far more universally spread out under the regur than is allowed above.

That the 'lal' or red sandy soil and the regur are both aqueous deposits is clear to any one who looks at them, and I am not aware that any doubt on this point has existed. But it appears to be a very unnecessary restriction or limitation of the source or cause of the formation of such deposits, to speak of them as only the result of lagoon or salt-lake action. Black soil of this kind is in course of every-day formation in every jheel or marsh in the country, at the distance of hundreds of miles from the actual sea, as well as close by. And there seems no reason whatever to suppose that the same processes of formation or deposition have not been in operation long before the surface of the country had entirely assumed its present form.

I think it equally certain that neither the black mud at the bottom of jheels nor the deposits in lagoons, would exhibit any remarkable resemblance to the typical characters of regur, until after these muds had been exposed to subærial influences for a considerable time.

Much of what is above (Chap. XII.) referred to as 'lal' is what by other writers has been called laterite. Another instance of the difficulty of getting rid of a lax use of a very indefinite term if once adopted.—T. Oldham.


Geological Survey Office Calcutta

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

KING, W., JUNR., *and* FOOTE, R. B. *On the Geological Structure of the Districts of* TRICHINOPOLY, SALEM, *and* SOUTH ARCOT, *included on Sheet 79 of the Indian Atlas.*

CLIFFS OF MAGNETIC IRON, ON THE GODAMULLAY

The Shevaroys in back ground

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. IV. Pt. 2.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR-GENERAL OF INDIA
IN COUNCIL.

UNDER THE DIRECTION OF

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CONTENTS.

NOTICE.

In the report, published in the preceding portion of the present Volume of these Memoirs (Vol. IV.), drawn up by Mr. H. F. Blanford, the results of a careful and detailed examination of the richly fossiliferous deposits of Trichinopoly and South Arcot, which belong generally to the Cretaceous period of geologists, have been given. The present report relates to the remainder of the area included in the same sheet of the Indian Atlas (Sheet No. 79). It is, purposely, not so detailed as the former, a vast portion of the area being composed exclusively of metamorphic rocks, which neither offer the same variety nor the same interest, as attesting succession of events, as the fossiliferous rocks. On some points, such as the valuable beds of Magnetic Iron ore, full details are given, but in general only the main features are alluded to. This portion of the country has been mapped almost entirely by Messrs. William King and R. Bruce Foote, who are the joint authors of the report.

The sheets of the Indian Atlas, being the only permanent form in which the results of the great surveys of India are published, have been adopted as the maps on which the geological lines fixed during the progress of the Geological Survey of India, should be put before the public. These sheets are, however, of considerable size, and owing to their comparatively small scale (4 miles to 1 inch), each sheet represents an area of more than 14,500 square miles. It is obvious that the careful examination of such an area would require a long time, and would, if done in any detail, spread over several years. And therefore, as no sheet can be published until the examination of the entire area embraced in it has been completed, a considerable time must often elapse before this can be accomplished. I anticipate that much of this unavoidable delay will be

obviated by the adoption, in this country, of the plan which has for years been in use on the Ordnance Survey of Great Britain, of dividing the larger sheets into four 'quarter-sheets.' Such a plan would render it practicable to give to the public, at reasonable intervals, geological maps of the country represented on each quarter-sheet, without the necessity of waiting for the completion of the whole sheet. Each of these quarter-sheets would embrace an area of more than three thousand six hundred square miles ! A reference to the annual reports of the Geological Survey of India will show, for instance, with regard to the country now referred to, that three 'quarter-sheets' of this map might have been issued years since.

No map is given with the present report, as it is supposed to refer to the sheet 79 of the Indian Atlas, geologically coloured, which is now in the engraver's hands awaiting publication.

THOMAS OLDHAM.

GEOLOGICAL SURVEY OFFICE,
April 1864.

In Mr. Blanford's report on the Cretaceous rocks, among other notices of the Cephalopoda found in those rocks, two species have had names attached to them as new, but have not been described. These are *Ammonites Tamulicus*, p. 118, and *Am. Madraspatanus*, p. 92.

Of these the former, *Am. Tamulicus*, is identical with a species already described by Roemer from Texas (1849) under the name of *Am. Guadaloupæ*. (See Palæontologia Indica, Series III, p. 90.) The latter species, *Am. Madraspatanus* (which name has been retained) is the species originally referred by Professor E. Forbes with a query to the species *Am. Juilleti* of D'Orbigny, but from which it is certainly distinct.

At various places also throughout the report *Am. Mantelli* is quoted. In most cases this is erroneous, much confusion between this and allied species having been admitted by the author of the report. (See Pal. Indica, Series III, page 83.)

Again, at page 141, it is stated that one of the shells from near Ninnyur is identical with *Turritella prœlonga*, Hislop, from the Rajahmundry beds. More careful comparison shows that this is not so.

The reader is requested to note these corrections.

GEOLOGICAL SURVEY OFFICE,
Calcutta, April 1864.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the Geological Structure of portions of the districts of TRICHINOPOLY, SALEM, *and* SOUTH ARCOT, MADRAS, *included in sheet No.* 79 *of the* INDIAN ATLAS, *by* WILLIAM KING, JUNR., *and* ROBERT BRUCE FOOTE, ESQRS., *Geological Survey of India.*

CHAPTER I.—*General Sketch of Area, &c.*

Area reported on.

The country referred to in the following pages may be described as a great rectangular area, bounded on the east by the Bay of Bengal; on the west by an imaginary line coinciding with the longitude 78° 8′ east of Greenwich; on the north and south by lines coinciding respectively with 12° 10′ and 10° 40′ north latitude. This tract of country, which is included in sheet 79 of the Indian Atlas, has an area of about 11,500 square miles, and, as might be expected, offers very considerable diversity of aspect and structure.

Physically, we must distinguish two great divisions of this area:—

1st.—The flat region occupying the eastern and southern parts of the rectangle; and 2ndly, the hilly region embracing the north-western portion. The former is part of what is known as the Payen Ghat, the true low country of the Carnatic; the latter forms geographically a great outlier of the Coromandel, or Eastern, Ghats,

and includes also a part of the southern end of the Baramahal terrace.*

Politically, the area under consideration includes parts of the following districts, Salem, Coimbatore, Trichinopoly, Tanjore, and South Arcot, with a few villages belonging to the Madura Collectorate, and the whole of the French territories of Pondicherry and Carical.

Drainage systems.

The Hydrology of this part of South India is very simple, all the surface being drained into the Bay of Bengal, and chiefly through four principal rivers; 1st, the Cauvery, the lower and middle portions of whose course receive affluents from this area, all the southern and western parts of which it drains; 2ndly, the Vellaur (the White River), which rises in the Tainandamullay range north-east of Salem, and receives the drainage of the northern end of the Kolymullays, the northern and eastern sides of the Patchamullay range, and of the southern and eastern sides of the Kalroyenmullay; 3rdly, the Punniar, which receives the drainage of the northern part, including the northern ends of the Shevaroy, Tainandamullay, and Kalroyen mountain ranges; and 4thly, the Ariankup river, which falls into the sea at Pondicherry, and is known also as the Gingee river.

Orography.

The principal mountain ranges, several of which have already been mentioned, are six in number.

1st.—The *Darmahpoor Mountains*, which lie in the extreme north-east corner of the area to be described.

2ndly.—The *Shervaroyenmullay*, (anglicised into Shevaroys,) lying south-east of the former range and north of the town of Salem.

* The descent from the Mysore table-land to the true low country of the Payen Ghat is no where quite sudden, being broken by the presence of an intermediate terrace of high ground, which either falls away regularly to the seaward, or else, as in great part of the Baramahal, is closed in by ranges of lofty hills or mountains, enclosing thus an elevated area of great dimensions.

3rdly.—The *Tainandamullay*, lying east of the Shevaroys, from which they are separated by the narrow Mungawaddy Pass.

4thly.—The *Kalroyenmullay*, lying east of the foregoing, and separated by the Cottaputty valley; this is the most easterly of the northern group of mountain ranges.

Divided from the above by the broad Salem-Ahtoor valley, and thus forming a distinct group as it were, are, 5thly, the *Patcha* or *Pucha-mullays* (Green Mountains), which lie immediately south of the Kalroyen; and 6thly, the *Kolymullays*, which are nearly due south of the Shevaroys.

Besides these, three or four isolated mountains and several lesser groups of hills must be enumerated—

a.—The *Godumullay*, a fine lofty mass in the centre of the Ahtoor valley, about 14 miles east of Salem.

b.—The *Boatha, Kedda,* and *Anandy Mullay,* three mountains between the Kolymullays and Salem; they are connected with the Kolymullay range by a rather elevated small plateau south of Jyelputty.

c.—The *Allavamullay*, a very steep-sided mountain, lying a few miles south-west of the Boathamullay.

d.—The *Tullamullay*, a fine bold mass between the south end of the Kolymullays and the Cauvery river.

Of the lower hill groups, the more important in extent are:—

1. The Cour or Tengricotta Mullay, north of the Shervaroyen range.

2. The hills south of the Toopoor river, between which and the Shevaroys, the Madras and Beypoor Railway attains its maximum elevation above the sea, viz., 1,510 feet at Mooroorputty.

c.—The Surragoo or Jergoor hills, south and south-east of Salem.

d.—The Neinahmullay, west of the Kolymullays.

e.—The Kannavoypoodoor hill, south of Namcul Droog.

f.—The Mulliakerry hill or Permalmullay, in the Ahtoor valley.

g.—The Pythoormullay, a knot of hills lying between the Patchamullays and Kalroyenmullay, and dividing the Ahtoor valley into two

parts. The Pythoormullay is connected with the small plateau above spoken of, lying south of Jyelputty.

h.—The Ellumbaloor hill, an outlier of the Patchamullays.

i.—The Iroor and Chuttramanny group of hills, south of the Patchamullays.

Distinct from any of these ranges is a series of more or less isolated hills of some magnitude, lying about half way between the Kalroyen range and the sea. These are the hills south and south-west of the famous Gingee Hill Fort, and are generally known as the Gingee hills. Gingee Fort, however, lies several miles beyond the northern boundary of the district now under description.

Besides the mountains and hills thus enumerated, there are a number of smaller isolated elevations, dotted about the low country, which will be referred to frequently in these pages, but which are not of sufficient size to be considered important physical features.

Baramahal plateau.

Holding a position intermediate in elevation between the mountains and the low country, we have the table-land formed by the southern end of the Baramahal terrace, which rises up gradually from north to south from the valley of the Punniar river to the foot of the Shevaroys and the Darmahpoor range. This southern part of the table-land is generally a very stony plain covered with stunted jungle and broken by a few low rocky hills. Near Darmahpoor, and at the foot of the Shevaroys, the greater thickness of soil renders the country much more fruitful. The table-land slopes to the east, and is joined to the Payen Ghat, or proper low country, by the Chungama Pass,* through which the Punniar flows towards the coast. The southern side of this plateau is connected with the lower country by means of the Mooroorputty Kanava (or pass), through which the Railway descends towards Salem.

* Through this pass in the last century Hyder Ali more than once poured down his armies on the hapless Carnatic.

From that point the country has a gradual fall southward and south-westward towards the valley of the Cauvery.

The low country occupies, as a glance at a map cannot fail to show, by far the larger portion of our area, and though much less diversified in surface than the hilly country, yet shows considerable variety of aspect, these variations in physical features coinciding in great measure with the changes in geological structure.

The greater part of the low country is occupied by rocks of sedimentary origin, resting on the metamorphic rocks, of which the entire mountain country is formed.

Features of low country.

The portion of the low country lying to the westward of the Madras and Trichinopoly road, north of a line drawn from the foot of the Kalroyenmullay through Kullakurichi and Tiagar to the same road near Arsinoor, may be described as a great plain sloping very gently to the east, and almost every where covered by jungle. The jungle, though often scrubby and open, is sometimes so thick as completely to hide the numerous villages scattered through it, and to render it necessary to have guides.* This plain is divided into two portions by the Punniar river, north of which the general level is broken by the most southerly members of the Gingee hill group before referred to, and by a few isolated hills lying at the east end of the Chungama Pass and to the north-east of the Kalroyen range. With the exception of three or four isolated hills lying close to the foot of the mountains, the plain south of the Punniar is broken only by a few very low rocky hills, such as the Panshar and Chengad hills near Tiagar Droog, and the Cunatur and Thendrencotta pagoda hills near to the Madras road.

Besides these, the plain is diversified only by occasional masses and ridges of rocks, such as those around Yellavanasur, which rarely

* Game is rather abundant in this jungle, and leopards, tigers, and other carnivora sometimes stray as far as the Great Trunk Road.

attain a sufficient size to stand much higher than the surrounding jungle.

South of the line above defined as extending from the Kalroyen range to the Madras road near to Arsinoor the country becomes more undulating, being cut into numerous ridges and furrows by the valleys of the Munimootaur and many other tributaries of the Vellaur rising in the above range. The country south of the Vellaur, sloping from the Patchamullays eastward, is very similar in its appearance, but a little less undulating in character. There is but little jungle on this undulating country, excepting quite close to the base of the Patchamullays. The same may be said of the rudely triangular area lying between the hills of the Ahtoor Pass and the confluence of the Vellaur and Pereyaur. Eastward of the Madras road the character of the surface becomes more and more tame, and it soon sinks into an almost dead level, excepting where broken by the low scarps of the small plateau of rocks belonging to the Cuddalore series, (see further on,) which rest on rocks of the Cretaceous period.

The scarps of these plateaux, although low, form rather marked objects on the northern and southern boundaries of the alluvial valleys of the Ariankup, Punniar, and Vellaur rivers. The surface of these plateaux where not cultivated is covered by low, scrubby, and often very thorny jungle. These plateaux in most parts terminate suddenly to the eastward, the alluvium resting against the foot of low lines of cliff.

Delta of the Cauvery.

Southward of the most extensive of these plateaux (that of Woodiarpolliam) the delta of the Cauvery forms an immense plain sloping down to the sea at so slight an angle as to present to the eye the appearance of an absolutely dead level.* This great plain is no where broken by the smallest

* The whole of this vast alluvial plain is so much cut up by irrigation channels, and the area under wet cultivation is so immense, that progress is generally impossible, except along the causeways or the high roads traversing the districts between the various important towns.

natural eminence until the coast is approached, when lines of blown sand hills appear, running generally quite parallel to the shore.

The physical features of the alluvial formations are generally very similar all along the coast. There are the same dead level and huge flats in the delta of the Cauvery as in the delta formed by the Punniar and Guddelom rivers, and also in the band of alluvium which joins those two great alluvial areas with each other, and with the alluvial valley of the Vellaur.

Along the coast, the narrow strip of beach is almost every where fringed by hillocks and ridges of blown sand, which not unfrequently occur in a double and triple row with all the characters of true "sand dunes." The sea rolls upon a shelving sandy shore unbroken by rocks of any kind; hence the coast is remarkably monotonous in aspect. The position of the alluvial formations running far up the valleys of the principal rivers, proves incontestably that considerable elevation of the land must have taken place since the deposition of the component materials of these the most recent of geological records in Southern India.

The sandy character of the superficial beds of the alluvium of the deltas of the Cauvery and Punniar, especially at their seaward extremities, is a remarkable feature, and shows that but for the supply of water furnished by the rivers themselves to the cultivators, the delta lands would ere long lapse into the condition of barren and desert-like sandy plains.

High ground south of delta.

To the south-east, the alluvium extends beyond the southern boundary line of the area now referred to, but proceeding westward from Negapatam, higher ground is met with on the south side of the road to Trichinopoly. This higher ground rises at first by a gentle slope over the great flat of the delta, but as we proceed westward, the slope increases, and beyond Tanjore has become quite abrupt, and is occasionally scarped. The plateau which is formed by this high ground is perfectly similar in character, in structure, and in appearance, to the plateaux before adverted to as

occurring between the Coleroon and Vellaur, and between the latter river and the Guddelom, and again on the north side of the Ariankup river.

About 10 miles to the west of Tanjore, the metamorphic rocks are again met with, and form the surface of the country up to the western boundary of our area. Here the character of the country generally is slightly undulating, with long low ridges, which extend in a north-east direction, and die away into the general plain as they approach the alluvial valley of the Cauvery. Only a few isolated hills of no great height occur in the metamorphic region south of the Cauvery, the chief of which are the Trichinopoly rock, the Punganur hill, the Retnagherry hill, and the Togamullay. The country is generally open and cultivated, but here and there jungly tracts of some extent occur.

Cauvery valley above delta.

The alluvial valley of the Cauvery westward of Seringham Island, which forms the head of the delta, offers no very special features of note. Its width diminishes gradually from about 3½ miles at the opening into the delta to 1¾ miles at the village of Shavindipolliam, where the Cauvery passes beyond the limits of our area. Like the delta, this alluvial valley is in a very high state of cultivation.

Country north of the Cauvery.

The country between the Cauvery and the mountains shows a very rough and barren belt of rocky ground running parallel with the Cauvery as far west as Moganoor, and about 4 or 5 miles in width. The country north of this rough zone becomes a tolerably level plain, broken only by a few isolated hills, *e. g.*, the Puggalawaddy pagoda hill and the Tullamullay, with a number of small subsidiary ridges. Proceeding westward and north-westward, the ground rises very gradually from an elevation of 236 feet at Trichinopoly to 511 at Namcul. Near the latter place the face of the country is scattered over with numerous rocky hills of various sizes, the chief of which are the Kannavoypoodoor hill, the Sunashamullay, and the Namcul-Droog hill. The country seems

generally barren, this appearance resulting, however, more from the absence of trees than from the unproductiveness of the soil. The character of the country is very similar all along the western side of the Kolymullays and the Shevaroys up to the southern edge of the Baramahal terrace, before defined. At Salem the elevation of the general surface of the country is 907 feet above sea level, and at Toopoor, 1,102. Eastward of Salem the great east and west valley rises, till the water-shed between the Salem river and the Vellaur is reached at the Maituputty Kanava ridge. Westward of this ridge, which is a spur of the Godumullay, the ground falls steadily, till the open country is reached. The country is in part rocky, with scrubby jungle, but the ground between the several hills is generally rather even, or but little undulated. The country north of Salem and up to the foot of the scarp of the Baramahal plateau is very much covered with jungle. Barren tracts of country, such as the (so-called) Chalk hills near Salem, are altogether the exception to the rule.

Climate.

The presence of high mountains and their peculiar position has of course a great effect upon the general climate of a country, and this is very markedly the case in Southern India, where some districts are protected from the influence of one or other of the monsoons, because of their peculiar position in relation to the mountain ranges, while other districts come under the influence of both these seasons.

North-east monsoon.

The country we are here treating of is principally affected by the north-east monsoon, which generally sets in in October and blows till March, when other winds sometimes prevail, accompanied by heavy thunder showers, (commonly known as the mango-showers,) which continue through April and May. In June the south-west monsoon generally sets in, and is felt, but to a lesser degree, over the whole of our area till September. In the eastern parts near

South-west monsoon.

the coast and up to the foot of the Kalroyen mountains and the Patchamullays, the greater part of the water supply is obtained from the north-east monsoon, which always gives rise to heavy freshets in the Vellaur and Punniar rivers. The great freshets of the Cauvery, however, depend upon the bursting of the south-west monsoon on the western ghats, where this great river takes its rise. By these freshets, which generally occur in June or July, the river is completely filled and not unfrequently it inundates the low country of the delta to a very great extent. On account of its proximity to the great Palghat Pass, the influence of the south-west monsoon is much greater over the country we are dealing with, than over the regions both further north and further south.

Influence of Palghat gap.

The south-west wind blows with great force into the Palghat Pass, which has a width of about 25 miles, diminishes a little as the mountains recede, and forms a funnel mouth out of which the wind issues. Afterwards it meets with little or nothing in the Coimbatore district to oppose it, till east of the Cauvery, the Shevaroys and Kolymullays break its force, and receive in heavy showers a large share of the moisture then remaining. A very strong current is almost without intermission urged through the Salem-Ahtoor valley as long as the south-west monsoon remains in force on the western coast. A similar and equally strong wind blows through that valley from the opposite quarter during the strength of the north-east monsoon. Southward of the Kolymullays no obstruction is offered to the westerly wind, owing to the absence of mountains, (the nearest being the Dindigal mountains, at a distance of some 40 miles,) and in consequence it blows very strongly across the delta to the east coast.* This easterly wind, added to the evaporation

* To the effects of this violent rush of wind from the Palghat Pass across the very dry Coimbatore district, Colonel Lambton, in his "Report on the Trigonometrical survey of the southern division," ascribes the formation of a rather extensive series of blown sand-

from the vast area of country laid under water in the delta during prevalence of the freshets of the Cauvery, tends to cool very greatly the otherwise intensely hot climate of the Tanjore district. The coast climate generally is much more damp and relaxing than that of the more inland parts of the low country, but the thermometer has generally a lower range near the sea.

The climate of the mountain plateaux is one much more agreeable and suitable to the European constitution in point of temperature, but unfortunately all the ranges are, during the hottest season, to a greater or less degree, the seat of malarious influences, giving rise to very dangerous jungle-fevers. None of the mountains, not even the Shevaroys, rise above the so-called fever range, and accordingly none enjoy an immunity from these dangerous diseases, which are as fatal to the Natives from the low country as to Europeans. April and May are generally the most unsafe months, and during these, the jungly regions, especially those among the lower hills, should be carefully avoided. During the cold season, however, especially in December and January, the malaria seems to be quite in abeyance; it is also said to be so for some weeks after the heavy rains of the south-west monsoon. Frost has been observed on the highest parts of the Shevaroys, but not, so far as we are aware, on the other ranges, which are of lesser altitude. The rain-fall on the hills is probably much in excess of that in the low country, but no reliable or sufficient data exist for any comparison. The climate of the Baramahal is decidedly much cooler than that of the low country, as the greater elevation would lead one to expect, but not sufficiently so to make any great difference in the general aspect of the flora of that terrace.

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hills in the neighbourhood of Darapooram, a large town on the banks of the Ambrawutty river, in the Coimbatore district.

It seems not unlikely that the blown sand hills mentioned below, as occurring near the junction of that river with the Cauvery, are likewise due to the action of the west wind.

Geology.

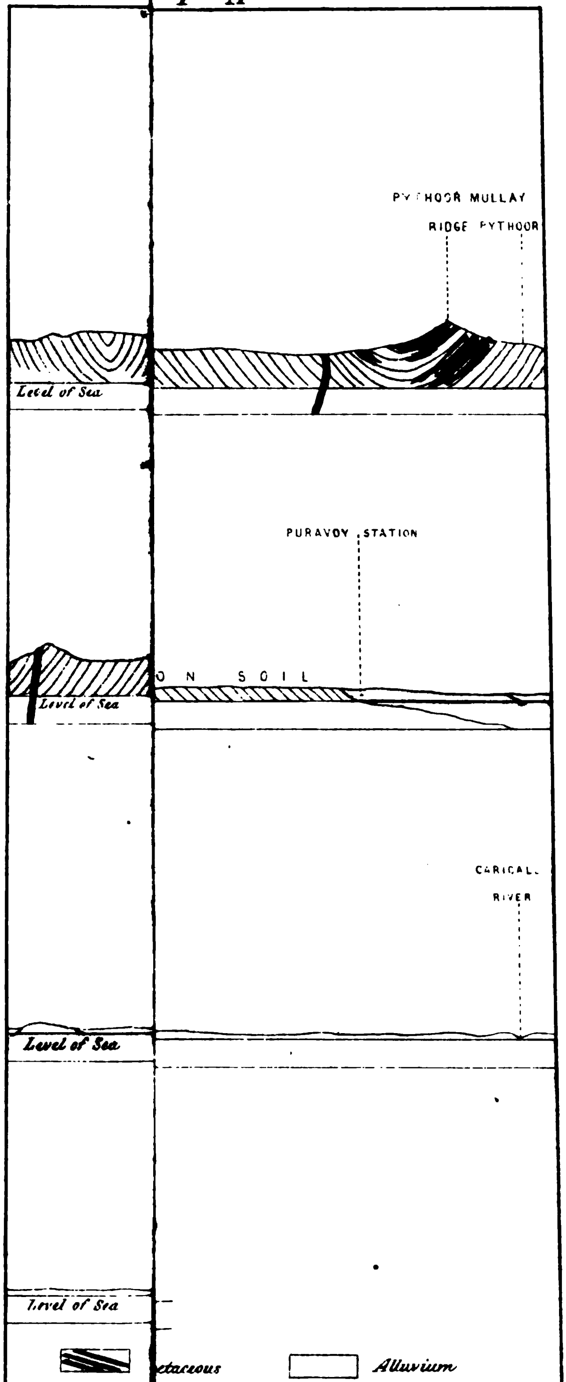
The general geological conformation of the country is very simple. The greater part of the area is occupied by metamorphic rocks belonging to the gneiss family; resting on these are three great groups of sedimentary rocks belonging to different geological periods, and overlying each other in regular succession from west to east. The first of these great groups belongs to the Cretaceous era. Resting upon these cretaceous rocks are, secondly, a group of rocks whose exact age has not yet been determined, owing to the absence of organic remains, but which are provisionally distinguished as the post-cretaceous rocks. Resting on these again are the beds of the fluvio-marine alluvium of the coast and river deltas. The sedimentary formations form great bands running in a north-east by north to south-west by south direction, and widening generally as they extend southward.

The general relative position of the geological formations to the descent of the country towards the Bay of Bengal is exhibited in the accompanying section from Salem to Negapatam (Plate II), on the scale of four miles to the inch. Of these great groups of rocks, those belonging to the Cretaceous system have already been described very fully by Mr. Henry F. Blanford in the preceding part of the present volume of the Memoirs of the Survey. In that report a description is also given of a small tract of metamorphic rocks lying between the cretaceous area in Trichinopoly district and the alluvium of the Cauvery delta.

Mr. Blanford's report treats also at some length of some parts of the post-cretaceous formations. With these exceptions, the present report will describe the whole area included in sheet 79 of the Indian Atlas.

Mountain groups.

As the mountain groups of the country embraced in this report are of great interest geologically and topographically, and are very frequently referred to in these pages, a brief description of the leading features of each will be found useful and



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interesting. Of the Darmahpoor Mountains there is little to be said. They form a long ridge, with breaks, stretching from Topoor* to the great Mookanoormullay, (generally known as the Darmahpoor hill,) which is the highest as well as most northerly part of the simple long extended ridge. The elevation of the Mookanoor hill cannot be less than 3,000 feet above sea level, and is probably very considerably more. Only the central part of the range is inhabited by a few Mullayalies, who cultivate castor oil and other dry crops on a small plateau on the western side of the ridge.

Darmahpoor.

The Shevaroys, the loftiest mountains within the area we are describing, present, when seen from the south, south-east, and south-west, a peculiarly massive appearance, but when seen from the north or north-east, they are found to be deeply indented by several valleys. This is especially the case on the north side, where there are two great bay-like valleys which run far into the mass of the mountain group. These are, the valley of the Topoor river, up which the Mulliapooram Ghat leads to the small station of Ercadu or Yercaud; and that of the Vaniaur river, a tributary of the Punniar, which drains by far the greater part of the Shevaroys. By this great ravine the mountain mass is deeply bisected for more than three quarters of its whole length, for the ravine commences about a mile north of Yercaud, and soon attains great depth. The back bone of the western of the two great lobes into which the mass of the Shevaroys is divided by the Vaniaur ravine, is formed by the "Green Hills" ridge, and is by far the most elevated portion, and also forms the water shed of the whole mountain mass. † The other lobe may aptly be designated as the Chentilloo lobe

Shevaroys.

* Topoor village lies about a mile beyond the western limit of Map No. 79, and a little to the south of the well-known pass of that name.

† The Shevaroys, if the generally assumed altitude of the summit of the Green Hills (5,260 feet) above sea level be correct, would appear to be the loftiest mountains in the Peninsula eastward of the Meridian of 78° longitude (east of Greenwich).

or spur, after the principal Mullayali village which stands on almost the highest part of the spur. The Tullasholay spur may perhaps be regarded as a third small intermediate lobe, but the ravine dividing it from the Chentilloo spur is only a shallow depression as compared with the Vaniaur ravine. There are upwards of seventy villages on the several plateaux. Excepting at the northern extremity, the flanks of the Shevaroys rarely show any fine precipices. The Shenguttapady precipices, however, are extremely grand. They consist of nearly perpendicular walls of bare rock, more than a thousand feet in height. The ten miles' journey from Yercaud to Shenguttapady is amply repaid by the grandeur of the view from the brow of these splendid precipices. The form of these precipices is dependent on certain causes which will be explained further on.

Tainandamullay.

The Tainandamullay range is divided by two breaks into three parts of very different sizes. The southern part, the Tainandamullay proper, which is by far the largest, is divided from the northern part of the range by a very deep valley stretching from Vellymardy to beyond Comboolooky. The lofty ridge thus cut off is known as the Carapandymullay, and is itself fairly separated from the Teertamullay by a deep saddle-shaped depression. The Tainandamullay proper is deeply cut into by four great ravines,—one on the north side at Taltooky, a second on the east, in which the village of Tandumputty is situated, and the third and fourth on the south side. From these two, which unite just before their opening into the Salem-Ahtoor valley, emerges the Vellaur river.

Kalroyenmullay.

To the east of the Tainandamullay, and separated from it by the great Cottaputty Pass, we find the Kalroyenmullays. The Cottaputty Pass is generally a level jungly valley from 1½ to ¾ths of a mile in width, and has no where the character of a narrow ravine, like the central part of the Munjawaddy Pass. The Kalroyen range is by far the largest of all in superficial extent, though in all probability holding only the fourth place in point of altitude,

which most likely does not in any of the peaks exceed 3,500 feet above sea level, if it attain so great an elevation.

Unlike the other ranges, it has no general name among the natives, but every principal division of the range bears a different appellation. Thus the extreme southern and south-west part goes by the name of the Pereya Kalroyen or the Great Kalroyen, and from this being the loftiest part of the range, has been (by us) selected to be applied collectively to the whole series of divisions. The low western part is known as the Chinna or Little Kalroyenmullay; the north-western extremity is called the Seel Naickenmullay or Aria-gowndenmullay. The north-east end has the name of Cooremboo Gowndenmullay, while the south-eastern part goes under the appellation of the Saria or Yaria Gownden Mullay.*

Divisions, &c.

In this range, as in the Shevaroys, and as we shall see presently in the case of the Kolymullays and Patchamullays, the greater part of the mass has a decided slope to the east, while only two streams of any size descend from the western slopes. The eastern and northern sides of the range are deeply cut by large valleys, some of great depth, as, for example, those of Kulpuddayoor, and Muttaparae and Toombay, which supply large streams uniting eventually to feed the Munnimootuur, the principal tributary of the Vellaur. When seen from a distance from the low country near Tiagar or Ellavanasur, the eye is struck by the nearly uniform levels both of the mass and of the various peaks, the summits of which appear nearly in one line. There is hardly any thing like a true plateau on the whole range, for the valleys are eroded into basin-shaped depressions. There are many Mullayali villages scattered over the range, still, from its great extent, the jungle is very extensive, and often, when containing much bamboo,

Summit plateaux slope eastwardly.

* Unless these names are known, it is almost hopeless to try to elicit any information from the natives.

(which, generally speaking, occurs in the valleys), quite impenetrable, unless actually cut through. The ridges often show timber trees of good quality, but dwarfed in size or of no great age. Those most frequently observed were very young Teak *(Tectona grandis)*, Vengay, *(Pterocarpus marsupium)* Kulmudre *(Terminalia coriacea)*, Vellay Naga *(Conocarpus latifolium)*, and sometimes Black-wood, *(Dalbergia latifolia)*. Where the trees are scattered but thinly near the tops of ridges, numerous dwarf date-palms and much lemon-grass stand between the different trunks. This applies to all the other hill ranges in very many cases. Very beautiful trees, rarely seen in the low country, but common on the various ranges, are the bastard Sago-palm *(Caryota urens)* which, with great Jack trees *(Artocarpus integrifolia)* and red cotton trees *(Bombax Malabaricum)* form perhaps the most striking botanical objects of these elevated regions.

Patchamullays.

The Patchamullays are of less elevation than any of the four ranges already described, and differ from them also in their shape, being of very irregular outline. Their greatest length, extending from north to south, is about 20 miles, measured to the extremities of the spurs respectively. In plan, the range has a very rude resemblance to an hour-glass in shape, being nearly cut in two by two ravines of great size and depth, opening to the north-east and south-west. Of the two parts thus formed, the north-western is the larger, and has generally a higher level than the south-eastern. Besides the rambling shape of the range, the most note-worthy and striking physical feature is the great steepness of the western slopes compared with those on the east, which are rarely precipitous, and are broken by sundry long buttress-like spurs, projecting far into the low country. In other respects these plateaux differ in no way from those of the other ranges. Like them they are inhabited by numerous Mullayali families of Vellala caste, whose villages in many cases are situated amidst lovely scenery, but are unfortunately

not exempt from malarious influences, deadly to all but the hill people themselves.

Kolymullays.

Westward of the Patchamullays, and divided from them by a broad valley, are the Kolymullays, which rise rather abruptly from the plains on the west, south, and east sides, but on the north and north-east, numerous long and gently sloping spurs descend to the low country. The range presents generally the appearance of a flat-topped mass of mountain land; in fact, one of the names given by the natives, "Sadura giris" (Square Mountains), shows their perception of this feature in the outline. Having from below such a level appearance, one might expect to find a tolerably flat plateau; but such is not the case, for within this outer and apparently uniformly level edge, the surface of the mountains is worn into five great basin-like depressions, the sides of which are further divided by numerous tolerably deep ravine-like valleys formed by the projection of spurs from the dividing ridges between the basins. This peculiar character is well shown in the map in the Indian Atlas, by which it will be seen that the northern end of the range contains one basin, the narrower central part a second, and the main or southern part three, namely, two small ones lying respectively on the north-west and south-east sides of the main basin, whose major axis lies from south-west by south to north-east by north. Over the eastern and north-eastern flanks the main streams of the mountains all flow either into the Toriore valley or into that drained by the Pereyaur; and it is only from this outer edge, or from some of the higher ridges of the interior that a view of the low country can be obtained. The greatest height observed was at the north end, where there is a ridge 4,016 feet above the sea, but the general height of the upper surface is not above 3,500 feet.

There is only one stream of any size occurring in the principal basin, and this runs in its course through occasional little alluvial flats which have been formed behind the hard bands of rock which are intercalated

Geology.

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Mountain groups.

As the mountain groups of the country embraced in this report are of great interest geologically and topographically, and are very frequently referred to in these pages, a brief description of the leading features of each will be found useful and

the limits of sheet 79, previously to its being taken up by the Madras party of the Geological Survey of India.

The earliest writer with whom we are acquainted, who touched upon the metamorphic rocks, was Dr. Benjamin Heyne, of the Indian Medical Service, who in his Tracts on India* described the rocks of various places within the area of our report. He frequently fell into the not unnatural error of confounding gneiss with granite and hornblende schist with syenite. He mentions in Tract XXII (Journal of a tour from Bangalore to Trichinopoly in 1802) the spreads of Regur with the underlying Kunkur occurring near Darmahpore in the Baramahal. Referring to the so-called Chalk Hills near Salem, he says, "I have lost the specimen of rock that constituted the forementioned low ridge; in my memorandum I find it was intersected by calcareous tuff, and contained in small nests a semi-pellucid greenstone, which, in its decomposed state, in which it principally occurred, crumbled into a powder which is carbonated magnesia. The sound stone is about the hardness of serpentine, and looks not unlike the famous image stone in China." The soil hereabouts is chiefly a black cotton ground; foliated hornblende appears often in rocks above it."

The next author who wrote about the geology of part of the country included in sheet 79 was Dr. P. M. Benza, of the Madras Medical Service, who, in his "Notes on the geology of the country between Madras and Neilgherry hills viâ Bangalore and viâ Salem,† touches upon several points in connection with the geology of Salem. He refers to the great number of fragments of quartz scattered over the plains near Adamancotta, but failed to notice that they are mainly derived from the degradation of one great granite vein

* Published in one volume, with maps and plates, London, 1814.

† Madras Journal of Literature and Science, Vol. IV, page 1 (No. 12, July 1836).

running from near Darmahpore south or south-westward, till it ranges beyond our limits a little to the north of the Topoor Pass. He points very clearly to the well marked stratifications of the hornblende schist of the hills lying between Adamancotta and Salem, although in many other parts of his notes he fails to recognize the real nature of the rocks, and confounds gneiss and granite. The subject of the magnesite veins near Salem is, on the whole, well treated by Dr. Benza. He appears, however, to have overlooked the presence of chalcedony and of serpentine in its fibrous form (Baltimorite), which are both of common occurrence; and also to have been unaware of the existence of the chromate of iron, which forms a remarkable vein in the central part of the tract of country covered by these magnesite veins.* An analysis of specimens of this magnesite by James Prinsep, Esq., is quoted in an appendix to the paper, the average results of 10 analyses being mentioned, as—

Magnesia	48·34.	
Carbonic acid	51·66.	
		100·00.

The second locality which he names (on hearsay) as showing an extensive magnesite formation, Yedichicolum, close to the Cauvery, near Trichinopoly, has not been identified during the progress of the survey. It can scarcely be considered to refer to a locality near Tripunguly, described further on, as that is but of small extent, and contains no chromate of iron. The Shevaroys Dr. Benza describes correctly as consisting of hornblende slate (schist). The Kunjamullay ("Cunjamullay") he strangely enough describes as wholly of green-stone slate, (meaning thereby, doubtless, hornblende schist,) overlooking the great magnetic iron beds, by a triple band of which the whole mountain is encircled, as well as some other non-hornblendic strata, constituting a great part of the mountain mass.

* The presence of this was, however, well known to the residents of Salem at that time.

In the Blue Book published by order of the House of Commons in consequence of the appointment of a Committee to enquire into the working of the original Porto Novo Iron Company, in all the numerous letters by Mr. Heath, the founder of that Company, and others on the subject of the monopoly of the iron ores in Salem and other districts, nothing is said as to the mode in which the magnetic iron occurs, nor are any of the localities indicated where such ore is to be met with. Similarly, although frequently alluded to in these letters and also in the leases granted by the East India Company to the Porto Novo Company of the monopoly of working the chromate of iron, as well as the magnetic iron, the locality or localities at which the chromic ores occur are no where named.

In the Geological Map of India compiled by the late George B. Greenough, the geological and physical structure of the country are very far from correctly laid down. The chief error which he fell into regarding the country now to be treated of, consists in ascribing to the several mountain ranges (which are not correctly laid down as to shape and position) nuclei of granitic rocks extending over the entire plateaux. The position of the cretaceous rocks is also too much to the westward, and encroaching on the metamorphic low country, and the post-cretaceous rocks have all been colored as alluvium only.

An important contribution to the knowledge of the geology of the Trichinopoly and Madras districts was supplied by the Reverend C. F. Muzzy, of the American Mission in Madura, to whom a copy of Greenough's Geological Map of India had been referred for report. In his reply to Government on that subject, (published in 1857,) after correcting numerous errors in the map, he proceeds to point out some of the more remarkable features of the country lying between the Collectorates of Tinnivelly on the south, and the Collectorates of Salem and South Arcot on the north. With regard to soils, he mentions that they usually agree with the subjacent rocks, excepting in the case of

alluvial soils near to the sea and to rivers, where of course the soils are true sedimentary deposits. The resemblance of some of these to the *Loess* of the Rhine is alluded to. The occurrence of basalt near the Vellaur river is noted, but the gneissic rocks adjoining are erroneously regarded as granite.

In speaking of the western part of Trichinopoly district, Mr. Muzzy alludes to a "small mountain" made up in part of magnesite, brucite, and other magnesian compounds. This is probably a reference to the magnesite veins occurring at Cajareputty, and described in this report further on. The great band of chloritic rock near Cunnanoor also came under his notice, though, strange to say, he appears not to have met with the great magnetic iron beds occurring in that immediate neighbourhood. Limestones occurring on the banks of the Cauvery near the upper anicut are alluded to but cursorily as of a Verde-Antique variety of marble. These are probably the beds of limestone discovered during the progress of the survey at Mootum and Naivailie on the banks of the Jyaur, which falls into the Cauvery just above the anicut at the head of Seringham Island. Mr. Muzzy refers further to magnesian rocks as occurring near Volcondapuram, in the northern part of Trichinopoly district, but does not describe them nor explain their relations to the metamorphic rocks upon which they rest. While correctly describing the granite veins of the left bank of the Cauvery as porphyritic in character, he has been misled in regarding the hornblende schists, which are very largely developed in that quarter, as syenitic granite. In speaking of the country south and south-west of Trichinopoly, the felspathic gneiss is treated as a porphyritic granite. Mr. Muzzy's notices of the cretaceous rocks, which are much fuller than those just alluded to, have already been referred to by Mr. Blanford in the first part of this volume.

In the summary of the Geology of India by Mr. H. J. Carter, of the Bombay Medical Service, appended to the "Geological Papers on Western India" edited and published by that Officer in 1857, a few

notices may be found of parts of the Salem, Trichinopoly, and South Arcot districts. At page 692, Captain Lawford is quoted as having observed "calcareous schists and magnesite" at Volconda; the schist was not observed by any of the several members of the Geological Survey who visited that place, and is probably but a local variation of the magnesite: and neither of the rocks have any real connection with the Cretaceous system. At page 641 a notice of the magnesite veins of the "Chalk Hills" near Salem, by the late Captain Newbold, is alluded to, in which the association of talcose schists with hornblende schists at Karpur (Caroopoor) is mentioned.

Other notices of the cretaceous and post-cretaceous rocks have already been reviewed by Mr. Blanford in the first part of this volume.

Mr. Blanford's report itself does not call for any remark in these pages, so far as it concerns the Cretaceous rocks, about which he has fully summarized the notices of previous observers, and correlated their views and those acquired during the careful examination of the district. The cretaceous rocks and their relations will therefore demand no further notice from us. It will be seen in the following pages that in some respects our more extended investigation of the district has led to different conclusions from those arrived at by Mr. Blanford,—differences not, however, affecting the real value of the results of the survey, nor materially altering the lines of boundary laid down, but restricted to questions regarding the mode of formation and age of one of the formations.

One or two minor errors of fact ought to be corrected; 1st.—The great band of granite veins north of the Cauvery is described as extending with undiminished breadth to Caroor. In reality the granite veins are not by any means numerous near Caroor; they almost totally disappear above the junction of the Ambrawutty river under alluvium. 2nd.—The height of the Kolamullay (Kolymullays) given at page 34, as

6,000 feet, in reality falls short of 5,000. The highest peak at north end of range gave us (1860,) only 4,016 feet. This is important, climatologically considered, as an elevation of 5,000 feet would render the hills safe from malarious influences.

CHAPTER II.—*Alluvial Deposits and Blown Sands.*

Position.

Deposition of alluvium has taken place along the whole sea-board of this part of Southern India, forming a continuous belt varying in breadth, which, in a westerly direction, runs up the valleys of the three main rivers, and of their tributaries; while all along the edge of the sea-ward belt, and occasionally further inland, ridges of sand have been formed by the winds prevalent in these localities.

Alluvia of the Cauvery.

The alluvium of the Cauvery extends over a very wide area, occupying a considerable part of the Trichinopoly district, and by far the larger half of Tanjore, and it strikes up in a northerly direction to join the alluvium of the Vellaur in the South Arcot district.

The Delta.

The delta commences at the head of Seringham Island, 10 miles west-north-west of Trichinopoly, where the Coleroon branches off, forming the most northerly of the many channels by which the water reaches the sea. Part only of the delta is described in this report,* the portion which lies south of a line drawn in a westerly direction from a point 5 miles south of Negapatam, in north latitude 10° 40′, not having come under examination.

Northern boundary.

The northern boundary of this alluvial valley, beginning at the western limit of the map, is formed by metamorphic rocks, which extend eastward, with a short intervening spread of cretaceous rocks, to Kullare, about 9 or 10 miles south of Arrialoor. From this point the cretaceous rocks, succeeded by Cuddalore sandstones, form the boundary; the latter formation gradually

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* The alluvium is known to extend as far south as point Calimere, about 30 miles, with a probable width of not less than 20 miles, forming thus an area of about 600 square miles in extent, which fairly belongs to the delta of the Cauvery.

trending north and forming a low promontory between the alluvial flats of the Cauvery and Vellaur rivers.

Along this side of the delta, as well as on the north bank of the Cauvery, west of Seringham Island, the alluvial boundary, owing to the more gentle rise of the country (except in the neighbourhood of the rugged granitic ridges of Erungaloor, and the spread of granitoid metamorphic rocks to the eastward) and the uniform character of the rocks across which the tributaries have worn their way, extends for a good distance up the courses of these. On the south side the boundary is much less sinuous, the streams having more the nature of torrents than of rivers; the country through which they flow rising rather rapidly, and being more rugged than that on the left bank of the Cauvery.

Alluvium of the tributary streams.

At the Trichinopoly and Tanjore side of the river the alluvium borders the gneiss formation from Caroor to Buttaloor, one of the stations of the Great Trigonometrical Survey, (now also a station of the Great Southern India Railway,) about 20 miles east of Trichinopoly. From this point the boundary in an easterly direction runs along grits (Cuddalore sandstones), the cretaceous rocks being absent. About 18 miles* east of Tanjore the boundary trends south-east, and extends beyond the limits of the sheet.

Almost the whole surface of the alluvial plain is under wet cultivation, and it is only along the coast, where there are blown sand hills, and in a somewhat elevated sandy tract between Shealli and Tranquebar, that wet cultivation does not predominate.

In many places the limit of wet cultivation coincides with the boundary of the alluvium, in others it has crossed and covered up the natural line of boundary, ren-

Cultivation of the alluvium

* The most southerly branch in the delta which, according to the map, leaves the Cauvery a little to the west of Tanjore, and crosses the limits of the map (79), is an artificial feeder of the great tank south of Murtiammapooram.

dering the exact determination and laying down of the same a matter of great difficulty and sometimes an impossibility. In the case of the tributary streams from the north, this difficulty occurred pretty frequently, for bunds have been built across the streams at various points, so as to form tanks, and these, with the artificial channels running parallel to the river, have assisted in the formation of alluvial flats extending often a mile or more beyond the true boundary.

obscures all boundaries.

Nature of the Alluvial Soils.—Two principal varieties of soil occupy by far the greater part of the surface of the delta, and are very nearly equal in extent of development; 1st, dark humus; 2nd, pale yellow sandy soil.

Soils of alluvium.

The dark humus occurs chiefly above and about the head of the delta, the sea-board and adjacent country having a decidedly sandy character; many parts indeed, if not irrigated, would speedily become a perfect desert. The humus is, where dry, not unlike cotton soil in appearance, but less friable; when wet, it has considerable plasticity, without, however, (in general) assuming a clayey character. The sandy districts, when well irrigated, are by no means unfertile, though vegetation has not quite the same unbounded luxuriance as on the dark soil. Clayey beds are very rare, the best marked is a hard ferruginous bed of clay exposed by the surf on the north side of the mouth of the Cauvery at Cauvery-patam (Cauvery-putnam). This bed is only exposed to a limited extent.

Blown sands of the Cauvery delta.—Of these, there is no great development between Devicottah and Negapatam, generally nothing more than a narrow ridge forming the inner edge of the beach. The exceptional cases are—

1stly.—Isolated lenticular patches of no very great extent, one on either side of the road, commencing about a mile south of Anagarachuttrum (at which place the Coleroon is crossed by a bridge

about 900 yards in length). No shells were found which might give a clue as to whether these sand accumulations are of marine or fresh-water origin, but the fact of its being a "sharp sand" favors the view of its fluviatile origin. If of marine origin, they must have advanced a long way inland from the coast, from which they are now 8 miles distance; if, on the contrary, these sand hills owe their origin to fresh-water, there is no difficulty in ascribing their formation to a change in the bed of the Coleroon, which would then appear to have shifted its course a couple of miles in a northerly direction.

2ndly.—From Koliar, a village 3½ miles north of Tirmelwassel (Trimelliwassel), a spur of blown sand branches off in a south-west direction, and extends (with one break) to the north side of the inlet. Tirmelwassel itself stands on a broad spread of blown sand.

3rdly.—A small patch north-west of Tranquebar.

4thly.—A ridge unconnected with the beach ridge, which runs from about 3 miles north of Carricall (Karikal) down to the north bank of the river.

5thly.—Between Karikal and Nagore are two smaller detached ridges.

6thly.—Southward of Negapatam, the blown sand runs about a mile inland from the beach, forming parallel and connected ridges.

Height of sand-hills.

The height of the sand ridges varies from 5 to 20 feet, rarely exceeding the latter elevation. The greatest elevation is attained by an isolated sand-hill, on which is built the Coopum, or fishing village of Negapatam. The sand-hill in this case is fully 50 feet above the surrounding beach, and commands a fine view over the level country all round.

Movement of sand-hills.

No general indications of a tendency to advance inland were observed. This comparatively stationary condition of the blown sand-hills appears to be caused by

the pretty equal effect of the monsoons ;* for, though the north-east monsoon blows on this coast with much greater force than the south-west, its transporting powers are negatived by the heavy rains, which, by saturation for a considerable time effectually bind the loose particles of sand. From Trimelwassel southwards, it was frequently observed that a dense jungle of Screw-palm or *Pandanus* intervened between the sand ridges and cultivated ground, offering a perfect barrier to the advance of the sand. In the Screw-palm jungle, small but beautiful glades covered with short fine turf occur not unfrequently. South of Negapatam, there are some very fine sand-hills, having a steep slope facing the sea. On ascending there, the landward side was found to be quite steep and backed-up by a thick jungle of trees and Palmyra palms. Further south the ridges are lower, and the tree jungle ceases, so that the sand extends further inland, until stopped by the *Pandanus* jungle.† That there is, however, some advance, is shown by the rapid silting up of a canal running northward from Trimelwassel parallel to the beach-line.

The Alluvium of the Vellaur.—The alluvial flat of this river may be said to commence from its junction with the Ellayaur,—a large stream

* This explanation is strongly confirmed by the observation of several residents on this Coast, among whom Messrs. Norfor and William Underwood, Junior, informed us that a particular sand-hill near Porto Novo regularly encroached on and covered a certain road during the north-east monsoon, and was as regularly driven back by the south-west monsoon, and the road opened again to traffic.

On various occasions, while engaged in mapping this line of sand-hills during the prevalence of the south-west monsoon,) immense quantities of sand were observed on dry windy days to be blown into the sea: this waste must of course be replaced, or the sand ridges would soon entirely disapear.

† West of Cutlay, a village on the south bank of the Cauvery, just below the junction with the Ambrawutty, is a hill of blown sand, raised most likely when the river is low and its wide sandy bed in great part dry. Another such hill occurs just within the apex of the angle caused by the junction of those two rivers, while on the north bank of the Cauvery, a few miles west of Moganoor, blown sand-hills are being formed on a small scale.

receiving affluents from the Kolymullays and Patchamullays. From this spot to beyond Andtoray, in South Arcot, the alluvium forms but a narrow band on either side of the river, which here widens out greatly, but narrows again eastward of Verdachellum to a width of about 5 miles. Eastward of the great Veeranum tank, it widens out greatly, the southern boundary trending rapidly to the south-east, till about 3 miles east of Lallpett, the alluvium of the Vellaur unites with that of the Cauvery delta.

Northern boundary.

The northern boundary trends away rapidly to the north-east by north, till at Cuddalore the alluvium of the Vellaur joins that of the Guddalam (Guddelom) and Pooniar rivers. Like the Cauvery alluvium, that of the Vellaur is bounded successively by the gneiss, cretaceous, and grit formations, in a direction from west to east.

Black soil of Vellaur alluvium.

Of the great expanse of the alluvium west and south of Verdachellum, much is uncultivated and covered by scrub-jungle; and it is here that perhaps the largest extent of black humic soil of all the alluvial deposits of the different river systems in this part of Southern India occurs. In this instance, the black soil approaches very closely to what is commonly called "cotton soil"; in fact, it may be said to shade, as far as appearances and constitution go, very gradually into the "Regur," which covers the country so extensively to the westward. That this wide spread of cotton-soil-like earth in the alluvial deposits of the Vellaur* is the result of an inland swamp or lake, which was backed up by the low plateau of Cuddalore sand-stones to the eastward before it was breached at the present passage of the river, can scarcely be doubted, looking at the physical structure of

* It is not impossible that much of this black alluvium is true Regur denuded away from the great spreads occurring on the higher grounds west of the Madras and Trichinopoly road, and washed up at this lower level during great floods, such as this river is sometimes subject to.

the country round about; the soil is exactly like that formed in the great Mercanum tank or back-water deposit lying to the north of Pondicherry, as well as the deposits formed and now forming in the beds of all the tanks about this part of the country.

A distinct boundary exists, however, between this soil as an alluvial deposit of the Vellaur basin and the cotton-soil of the higher grounds to the westward; and therefore we have included it among the alluvial deposits of the river, and refrained from classing it as cotton-soil proper, until the subject of the different soils of India has been more fully worked out.

Cliff Section at Bhowanaghiri.

The surface of the alluvial flat north of Chellunbrun is more elevated than that nearer the Coleroon; for the Vellaur runs in a deep bed with steep banks, forming, at Bhowanaghiri, regular cliffs, at the base of which the upper beds of the Cuddalore sand-stones are exposed. At Tolum, where there is a Government ferry station, and beyond which place the tide extends, there is a bed of peat exposed only at ebb tide. The peat consists mainly of leaves and fruits of dicotyledonous trees, still preserving, in great measure, their characteristic shape. Here, likewise, the river runs between cliffy banks, 20 feet or more in height.

'Peat' at Tolum.

The Vellaur does not form a delta, discharging its waters into the Bay of Bengal by one mouth at Porto Novo.

Blown sands.

North of Chellunbrun, on the west side of the road, is a small ridge of blown sand running north by east to within a few yards of the Vellaur. It is overgrown by numerous large Palmyra palms. Excepting those two patches of blown sand south of Anagara Chuttrum, this is the most westerly of all the blown sands along the coast, from which it is distant fully 6 miles.

The mouth of the Vellaur is little more than 4 miles from the most northerly arm of the Coleroon, which falls into a sort of lagoon formed by some islands at the mouth of the main river.*

Between the two rivers the blown sand scarcely forms a ridge, but rather a flat expanse, with numerous isolated hillocks, amongst which at Killay, opposite to Porto Novo, there are rather extensive salt-pans. North of the Vellaur the blown sands occur in several high and extensive ridges, besides the coast ridge, which is of great breadth, and extends up to Fort St. David.

Soils of the Vellaur Alluvium.—The remarks made on the soils of the Cauvery delta and river flat apply equally well here, the black humic earth and pale sandy soil both occurring, though the latter is proportionately less developed than the former.

Marine beds in the Alluvium.—That at no very ancient period (geologically speaking) the sea washed the base of the promontory terminating in the cliffs of Capper's Hill (at Cuddalore), is incontestably proved by the existence of beds abounding in fossil marine shells of existing species at Kandyamallur, a village near the southern extremities of the great Permalyeri tank.

The quantity of shells here is so great that they are largely used for the purpose of making a very fine quality of chunam (lime). These beds seem to stretch away right to the coast in an easterly and north-easterly direction, and in a southerly direction the fossil shells were observed on the west side of Chugenvilli tank, beside a group of Palmyra palms. Many shells were collected where the high road crosses the river by which the surplus water of the great tank is carried into the Cuddalore back-water.

* This creek abounds in mollusca, crustacea, and fish. Muggers (*Crocodilus biporcatus*, Cuv.) were also observed.

Most of the species found sub-fossil at Kandyamallur were also collected by us, either living or quite fresh, on the adjoining coast, and in the creek and back-waters at the mouths of the Coleroon, Vellaur, and Guddalam. Indications of a similar deposit, a few miles west of Cauverypatam, in Tanjore District, have already been adverted to. The sands along the coast are generally quartzose, but here and there, as at Fort St. David and Cauverypatam, there is a considerable quantity of black magnetic iron sand, and, at the latter place, a patch, several square yards in extent, of red garnet sand, was noticed.

The blown sands north of the Pooniar extend up to Pondicherry. The coast ridge from the northern mouth of the river up to the fishing village of Pylittel is more than usually elevated, averaging about 25 feet. It is separated from the large flat of sand, which extends to beyond the high road, by a little valley, now under wet cultivation, which would appear formerly to have been a back-water. The same thing also occurs on the island between the two branches of the Ariankuppam river, both of which, as well as the southern arm of the Pooniar, were, when examined, closed by a bar of sand, thrown up by the heavy surf which prevails on this coast.

CHAPTER III.—*Post-cretaceous rocks.—(Cuddalore Sandstones.)*

This name has been assigned by Mr. Henry F. Blanford to an important series of rocks, resting immediately on the cretaceous formations found in the South Arcot and Trichinopoly districts.

This series of rocks occurs in four distinct areas, separated by the valleys of the Punniar, Vellaur, and Cauvery rivers.

Four areas.

The four areas are, in all probability, parts of a great continuous deposit over the eastern side of the Carnatic, which was cut through, and in great part denuded away during the formation of the valleys now occupied by the abovenamed rivers.

Originally continuous.

The four areas have the form of low table-lands or plateaux terminating in low but abrupt headlands on their northern and eastern sides, around which the beds of the present alluvium have been deposited.

On the south side of the Cauvery, the Cuddalore series appears to rest immediately on the metamorphic rocks, the cretaceous beds, if they ever covered those parts, having been in great part, if not entirely, denuded away previously to the depositions of the post-cretaceous formations.*

Owing to the absence of any fossil remains, excepting some tree-stems found at Tiruvakary, near Pondicherry, the exact age of this rather extensive formation is as yet undecided; fossil trees not offering sufficient data whereby to refer these beds to well-determined horizons amongst the recognised tertiary or quarternary formations.

Age undecided.

As indicated by the name "Cuddalore Sandstones," this series of rocks consists mainly of more or less ferruginous sandstones associated

* Since the country south of the Cauvery was examined by us, fossiliferous beds underlying the Cuddalore series are reported to have been exposed near Tanjore, in cuttings made during the construction of the Railway from Negapatam to Trichinopoly; but we have been unable to procure any of the fossils from these rocks, which are probably of cretaceous age. No outcrops of the cretaceous rocks have as yet been observed anywhere south of the Cauvery.

with mottled grits, containing numerous cavities filled with clay and occasionally beds of clay. Resting upon these, occurs very generally a highly ferruginous conglomeratic deposit of indurated clay, well known as laterite.* This laterite is in many places apparently inseparable from the soft mottled grits, and seems to pass downward into them by imperceptible gradations.

The association, however, in some places of this laterite with other and older rocks which will be presently described, together with its very peculiar composition, structure, and appearance, renders it desirable that it should be considered separately from the Cuddalore sandstones. We shall therefore adopt a lithological distinction and divide the Cuddalore sandstone series into two groups.

b. Lateritic deposits.

a. The grits.

As Mr. H. F. Blanford has already fully described the second group, or " the grits," our remarks on that group will be very brief.

At Tiruvakary.

a. The grits.—These are well exposed at Tiruvakary, where they contain many stems of large exogenous trees. The grits there are light coloured, and show much false-bedding, a character which is particularly clear, because many of the laminæ are of bright, pink yellow and purplish colors, which contrast strongly with the general more or less white tint of the rock. The grits are more than usually consolidated at this place; not sufficiently, however, to make a good building-stone. Soft mottled grits are also extremely well shown at vari-

Trivandipuram

ous points along the scarp on the north side of the Cuddalore plateau, especially at Trivandipuram, on the banks of the Guddalam river, a few miles west of Cuddalore.†

* A deposit of identical character extends interruptedly from the neighbourhood of Madras northwards to beyond Nellore.

† The section of the Cuddalore series at Trivandipuram, on the bank of the Guddalam river, near Cuddalore, was vividly recalled to my mind by the very similar show of colours

Again, at Tanjore, above the fort, and in the ditch of the little fort or citadel, there is a fine display of mottled grits, which are covered up by pale drab or reddish sands passing to the south-east and east, and the grits are but rarely seen.

and Tanjore.

On the top of the rising ground immediately east of Vellum stand the remains of an old square fort, surrounded, except at the north-west corner, by a deep moat dug out of the mottled grits. Close to the north-east corner of the moat, and exposed by the denuding action of a spring emerging from the grits, are some boulders of whitish chert imbedded in the grits. These boulders have a very close resemblance externally to the extremely hard limestone occurring at Naicolum, near Ootatoor.

Chert in the grits.

They contain some fossils, such as a species of *lithophagus*, cast of a *terebratula*, a *coral*, and impressions of clavate (club-shaped) spines of a variety of *cidaris*, which, however, have not yet been compared, consequently the age of the beds whence these boulders are derived is uncertain, but they are most likely of cretaceous age.*

Fossils in chert.

Several more blocks of this cherty rock are to be seen at the foot of the causeway crossing the moat, and fragments are strewed about inside the fort, by which attention was first drawn to the matter.

The mottled grits occasionally contain numerous pebbles of different varieties of quartz; and rock crystal, smoky quartz, cairngorms, and amethysts are not unfrequently found in the various nullahs running off the grits-plateau near Vellum. These are collected by the native lapidaries, and cut into various ornamental and useful articles, which are sold under the name of *Vellum stones*. (See Chapter on Economic Geology.)

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presented by the variegated laterite of Shooranoor, on the bank of the Ponany river, in Malabar and Kotium (Cottaum), in Travancore, in which latter place I found numerous small but well-rounded pebbles of white quartz imbedded in the solid laterite.—R. B. F.

* These fossils were lost in the wreck of the "Aurora" on their way to Calcutta.

Pot holes in the grits.

In the first small nullah which runs under the high road about 1½ miles east of Vellum, and reaches the low ground to the north of Pullayaputty, are several small but well marked and instructive examples of pot holes formed by the grinding action of pebbles rapidly rotated by the eddies in the stream. In several of the pot holes the pebbles were still lying, the force of the stream not having been sufficient to wash them out of the steep-sided holes they had been instrumental in scooping. Westward of Vellum nothing more is seen of the mottled grits, the whole surface being thickly covered with red soil mixed with black laterite.

At Verdachellum, in a quarry lying north of the Polygar's Bungalow, a bed of true sandstone is exposed, which is sufficiently compact and tenacious to be worked into slabs and troughs. It is of a pale color, varying from yellow to a pinkish drab. The most frequent character superficially in this locality, is that of a tolerably compact brick-red sand, with here and there marly and clayey patches of small extent, but almost invariably also of red colour. Very few good sections are to be found over the country occupied by these rocks, which has necessarily greatly hindered us in obtaining a sufficient acquaintance with their detailed structure.

Thickness of grits.

The thickness of this formation in proportion to its wide superficial spread is very small, and may, with tolerable safety, be estimated at about 100 feet. Between Tanjore and Vellum, where it is very extensively exposed, it rises to a height of not much more than 60 feet above the general level of the alluvial flat which lies at the foot of it, and here it is most likely exposed, judging from the very gentle easterly slope, nearly down to its face. In the Cuddalore plateau, the thickness of the formation would appear to be rather greater, if the height of its northern scarp be a correct index; in other words, if the whole thickness of beds there exposed belongs to the Cuddalore series, which would appear to be the case.

b. Lateritic Deposits.—These singular deposits occur, as before mentioned, very generally on the top of the grits series, without any apparent unconformity; they were not, therefore, during the progress of the Survey, separated from the Cuddalore series, and appear on the map represented by the same colour. A well marked instance of the apparent passage of the overlying laterite downwards into the mottled grits, occurs at Vellum, in the moat of the old fort, as already noticed by Mr. H. F. Blanford.*

The same may also be well seen in the small nullah east of the fort, where the pot holes are excavated in lateritic mottled grits.

Notwithstanding this intimate association of the laterite with the grits, there appears to be an unconformity when their relation over a larger area is considered, and this we shall endeavour to illustrate after having considered the general lithological character of the deposits.

Lithological character.

This brown ferruginous deposit, usually called Laterite, occurs in two forms over this district; as a regular aqueous deposit of great extent, or as the effects of decomposition *in situ* of highly ferruginous rocks. It will be seen that these are virtually the two forms described as "Laterite" and "Lithomarge" by our colleague Mr. W. T. Blanford in his Notes on the Laterite of Orissa.† This character is well shown in the typical laterite capping the mottled grits both at Capper's Hill near Cuddalore and at Tanjore, though the latter form, as far as we have seen, does not occur as therein described (*i. e.*, underlying the true laterite).

The latter variety has been observed, in two or three localities south of the Cauvery, as an assemblage of blocks in the bends of streams, where a small quantity of water almost constantly remains; and that it is essentially decomposed gneiss *in situ*, is evident, since the foliation is distinctly visible, as well as the gradual change from a dark reddish-

* Memoirs of the Geological Survey of India, Vol. IV., Part 1, page 167.

† Memoirs of the Geological Survey of India, Vol. I, page 280.

brown friable *surface* of sandy clay to the true rock internally; the folia of quartz still remaining as needles or ridges in the decomposed parts of the block. This is identically the same as the pseudo-lateritic formation on the Nilgiri and Shevaroy Mountains, which is there a decomposed gneiss.

The laterite proper consists essentially of an agglomeration of little rounded particles cemented together by a ferruginous sandy clay, the little nodules or concretions being more distinct in their form towards the upper surface, where they become darker in color, gradually changing from a yellowish-red to dark brown or black, eventually becoming quite polished, and assuming a semi-metallic lustre. Generally, these consist of ferruginous sandy clay, concretionary in structure, but in many cases they are composed of iron-ore, showing a grey metallic surface when broken; grains of sands also are frequently included in the mass, which sometimes assumes a true conglomeratic character. The matrix or cementing material increases in quantity from the interior of the bed to the surface, the latter being harder and less friable than the interior, which is clayey. In its least compact form, this formation occurs as a gravel-like accumulation of small rounded pellets of impure, clayey, brown Hæmatite, for which the very suitable name of "pisiform lateritic gravel" has been proposed by Dr. Oldham. Beds or large nests of pale yellow and white clay occur with the laterite, as may be seen on the eastern edge of the Thoongoody patch in the Trichinopoly district, where a hole has been excavated for road material down to this clay, which is quite soft, and when, as is often the case, covered over with a thin coating of blown lateritic gravel, peculiarly deceptive in its appearance of firmness. This case of soft clay would seem to indicate an underlying variety or Lithomarge, but no section was found sufficiently deep to show the relation between the clay and the underlying rock, which is gneiss.

Pisolitic and tubiform character.

Where the deposit is thoroughly exposed on all sides, as at a spot 7 miles south-south-east of Trichinopoly, where a stream has cut through the laterite, as well as the gneiss on which it rests, the vertical section shows a regular pisiform structure throughout, accompanied by tubiform cavities, though of a more ferruginous character towards the upper surface. It is mainly on the sides and under-surfaces of blocks that the tubiform character is seen; the upper showing them less frequently. Of the cause of these tubiform vermicular cavities, no altogether satisfactory solution has yet been offered, nor did the phenomena observed by us suggest any as yet unobserved cause to which to attribute them.*

South of Vellum there is a section in a stream showing, at a depth of 3 or 4 feet below the surface, very cellular laterite permeated by

* Since the examination of laterite in the country described above, more extended observations of that rock in the Nellore district, where it is largely quarried, have been made, and these, taken in connection with what we have seen of laterite in South India, appear to indicate a reason for the occurrence of the tubiform cavities. This peculiar structure is developed *only*, or perhaps more correctly *to the greatest extent*, in superficial laterite,—that ferruginous, sandy, or concretionary clay which has become, through exposure to atmospheric influences, what is peculiarly called laterite. This clay is very varied in its composition, being streaked and mottled with little strings and nests of differently constituted clays. In the Nellore quarries especially, as well as in the Tanjore and Trichinopoly laterite, I have observed that the freshly cut blocks of rock are not nearly so visicular as those which have lain about on the ground for some considerable time: and the quarries are excavated in successive flat horizontal terraces until a depth is attained at which the rock is scarcely at all porous and too clayey for the required purpose, when the place is left to be again resorted to after the newly exposed rock may have assumed a harder constitution.

Taking the above facts into consideration, it would appear, then, that evaporation, contraction, and the varied constitution of the rocks, in so far as it consists of nests and strings of more or less ferruginous, or sandy, or aluminous materials, may have tended to the formation of hollows and vermicular cavities whence easily disintegrated matter may have been removed by percolation of water.—W. K.

irregular pipe-like cavities of a yellowish-brown color, which is more clayey in its constitution than that of the surface.

Conglomeratic laterite.

Though of so uniform a structure over great part of its extent, the laterite becomes highly conglomeratic in many places, especially in the outlying patches south and south-east of Trichinopoly. Here, as on the Brigade-ground, and a mile and a half south of the Race-course, it encloses sub-angular fragments of quartz and gneiss, of sizes varying from that of a small pebble to pieces of 3 or 4 inches in diameter. At times the quantity of these is so great that in the latter locality they almost make a pavement, having, as it were, its seams or joints of laterite. A conglomerate of quartz fragments is, however, the most ordinary form. Occasionally, the laterite is a coarse deposit of small particles of quartz in a matrix of ferruginous sandy clay.

Physical features of laterite country.

The laterite characterizes the country over which it is developed by its peculiarly flat or table-land surfaces, which are sometimes of great extent, as may be well seen on the Vellum table-land, or to a less extent south and south-west of Thoongoody. Where the ground rises above the general level, this deposit laps round it, leaving an island of the subjacent rock, or where parallel streams have worn their way as they flowed down from the higher grounds, we find the laterite denuded from all but the low ridges between the streams, showing its scarped edges in contour lines along the sides and round the heads of the valleys. Most interesting examples, on a small scale, of this last feature, are observable to the south of the Trichinopoly Race-course.

Unconformity of laterite and grits.

The probable unconformity of the laterite to the mottled grits of Tanjore and Vellum is assumed for the following reason: that the laterite greatly overlaps the grits, stretching for many miles westward over the gneiss rocks in the direction of Trichinopoly. Of the existence of the overlap, there can be no

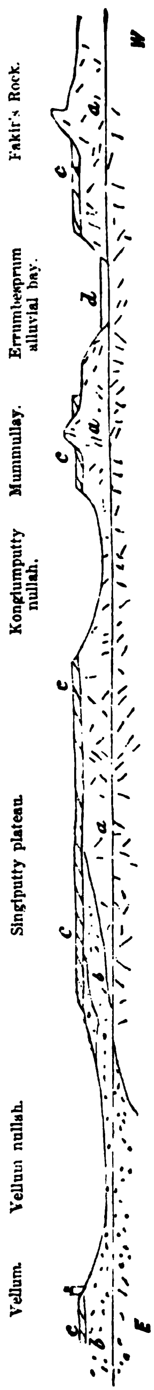

FIG. 1.—SKETCH SECTION FROM VELLUM TO THE FAKIR'S ROCK.

a, Gneiss: *b*, grits: *c*, laterite: *d*, alluvium.

doubt whatever, as the contact of the laterite and gneiss is exposed to view in many places.

Mr. H. F. Blanford has assumed that no grits extend to the westward of Vellum; it is true that none are exposed on the high ground west of the great Vellum nullah, but the whole of the ground there is so thickly covered with dark red soil and black laterite, that the nature of the underlying rock cannot (or could not at the time of our visit) be determined. But the lower beds of the grits are unquestionably exposed in the nullah close to the village of Vanarapata, and as the eastward dip of the whole formation is very slight, there seems every reason to believe that it extends westward across the horse-shoe-shaped valley of the Vellum nullah, and thins out on the gentle slope of the gneiss between Vellum and Singiputty. If the grits do not die away on the gentle slope of the gneiss, they must abut suddenly against a head-land of it, and it seems very unlikely that this could be entirely hidden by the talus of red soil and laterite.

Further, the general outline of the rising ground on the west side of the nullah does not indicate any change of rock to have taken place.

The sudden termination of the grits at Vellum would only make the overlap of the laterite much greater than we are inclined to regard it.

The accompanying Section, Fig. 1, will help to explain the true nature of the overlap.

Boundary of laterite to west.

The red soil and black laterite identical (in appearance) with the surface laterite (east of Vellum) extends to about 5 miles west of Singiputty. The laterite then suddenly ceases and gives place to a

flat shallow valley filled with white soil, abounding in quicksands along the banks of two or three large nullahs which run north. This white soda-soil lies on the gneiss, which, however, is only occasionally exposed, as, by the side of the road a few hundred yards west of Buttalur (Buddelur) Trig. station, to which place the boundary of the Cuddalore sands trends generally north-east from the spot where it crosses the Trichinopoly road. This white soil is not only very barren, producing little more than low prickly gum-tree (*Babul*) jungles, but, owing to the large quantity of soda and potash it contains, is very unstable, causing very serious trouble in maintaining the earth-works in connexion with the high road and the Great Southern India Railway (between Trichinopoly and Negapatam).

On the left or west side of the valley above referred to, about half a mile east of the Travellers' Bungalow at Thoongoody, the laterite again appears, in all probability a continuation of the Singiputty deposit. It here makes a considerable spread in all directions, but chiefly to the south, where it extends beyond the limits of the map. It forms a bay round the Mummullay (a group of low rounded gneiss bosses), and spreads northwards almost down to the alluvium, from which it is divided by a narrow strip of gneiss. The higher grounds are regularly capped by it, and numerous small springs issue from below the scarped edges, which form a contour line along the slopes. It confines itself almost entirely to the higher ground, being scarcely ever found in the depressions occupied by existing streams.

Crossing the great bay of alluvium which runs south for some miles from the Errumbesprum Pagoda Rock, there is another large patch of laterite-conglomerate, which commences about a quarter of a mile north of the new Trichinopoly Road, crosses the old road a little south-east of Ponmullay (Golden Rock), and making a bend like the lower limb of an S, terminates a few hundred yards west of the village of Sunthasaputty, and about 1¼ mile south of "Fakir's

Rock," at Trichinopoly. Three small isolated patches at the villages of Rangumputty, Eatchacamalputty, Goondoor, and Poodoor indicate a former connexion with the eastern or main patch. Westward of the Coreyaur, (an affluent of the Cauvery at Trichinopoly,) no lateritic conglomerate appears, excepting a very small patch only a few yards square at the western extremity of the southern tank at Baker's Choultry (Rotikaranchuttrum).

There can be little doubt that this laterite south-east of Trichinopoly is a true sedimentary formation like the laterite of Tanjore and Vellum, and is not to be ranked among the sub-aerial pseudo-laterites, such as those of the Nilgiris and Shevaroys, which have resulted solely from the oxidization of weathered ferruginous materials, and mainly from the hornblendic or amphibolitic rocks of those mountains. Should it be imagined, however, that it is a laterite formed by the decomposition of the gneiss rock *in situ*, there are several valid objections to that supposition, and it will most likely be established, when the country around Poodoocottah (in Tondiman's territory) shall have been surveyed, to be of the same age as, and a continuation of, the laterite lying on the mottled grits of Vellum and Tanjore.

The objections to the application of the decomposition *in situ* theory, in this case, are principally three:—

1st.—The underlying gneiss rock when exposed is almost invariably quite fresh and undecomposed in contact with the bed of lateritic conglomerate; whereas, had decomposition *in situ* been the cause of the latter formation, there would be evidences of such decomposition in the shape of only partially decomposed portions of gneiss at the line of junction. Such, however, is scarcely ever the case over the whole laterite areas westward from the Konjumputty valley.

2nd.—The formation of such masses of ferruginous rock could only take place by the decomposition of a rock containing an abundance of iron among its constituents, as, for instance, very hornblendic gneiss, etc.;

but in this area highly ferruginous varieties of gneiss are almost unknown, quartzose or felspatho-quartzose gneiss forming the great mass of the country.

3rd.—The position of the bed of laterite and its conglomeratic structure (containing rounded and sub-angular fragments of quartz) are two points, both of which are opposed to the decomposition *in situ* hypothesis. The occurrence of rounded fragments (almost pebbles) of quartz in the conglomerate cannot be explained by supposing the edges to have been blunted by weathering; but there is no difficulty in obtaining an explanation if we refer the phenomenon to a process of attrition previous to deposition, the whole of the materials composing the laterite appearing to have been conveyed from a distance.

As before mentioned, there seems reason to consider this bed as having been originally continuous with the superficial laterite occurring at Vellum, and therefore as a continuation and thinning out of the laterite westward, as shown in the Section at page 42.*

The flora on the grits formation is characteristic of an extremely dry soil marked by the absence of trees requiring much moisture, such as cocoanut, palms, and bamboos, and the occurrence of extensive jungles of low, scrubby, prickly shrubs, as to the south-west of Cuddalore and at Ammahpettah, and of large topes of the Palmyra-palm. Jack trees thrive admirably around Verdachellum, and topes of large fine Mango and Ellipoo *(Bassia longifolia)* trees are not uncommon. Where an abundant supply of water can be got, rice cultivation is carried on, and the soil seems not unfruitful; but compared with the alluvium, the whole country has a barren aspect. The surface is level, or only slightly undulating, without any rise worthy of the name of a hill.

* A similar relation probably subsists between the two small outliers of laterite occurring at Anawari, 4 miles south-east by south of Tiruvananullur, and the grits-plateau of Cuddalore.

Still, owing, however, to the fine contrast between the red soil and green foliage, there is some pretty scenery. In many places the water is so highly charged with iron in solution, that even after filtering, it retains a dark reddish brown coluor, which, however, does not give it any bad taste, though it stains linen-clothes.

Economically considered, the grits and laterite furnish little beyond tolerable building stone, and a fair road material, owing to its aptitude for binding. Wherever it is procurable, the roads ought to be in good condition, and when not at too great a distance, its good qualities are well worth a large outlay in the cost of carriage. These remarks apply specially to the south-east corner of South Arcot, the north of Tanjore district, and some parts of the south-east of Trichinopoly district, where the laterite is either at hand or at no very great distance. A few additional remarks on adaptation of laterite to building purposes will be found in the Chapter on Economic Geology.

Chapter IV.—*Metamorphic rocks.*

1. Gneissose Rocks.

a. Varieties of gneiss.—The Metamorphic series, as developed in the country here treated of, embraces a great succession of gneissose rocks of various kinds, (chiefly of the hornblendic varieties,) and of crystalline limestone in comparatively small quantity. This series constitutes the bottom rocks of the country, no older formation having been discovered, and is overlaid successively by cretaceous rocks, the Cuddalore sandstones, and superficial deposits of alluvium, &c. The different members of this series have undergone great contortion in some districts, and have been broken through by numerous granite veins, and traversed by dykes of greenstone and other trappean rocks, and by veins of quartz.

General character.

A very common and widely distributed form of these rocks is that of a dark grey, hard, compact, massive syenitoid gneiss, of quartz, hornblende, and felspar, in which the constituent minerals are pretty evenly distributed. It is this general type of rock which mainly constitutes the different mountain masses in our area. This is also the typical form of rock in the Nilgiris and in the Anamullays, two great hill-ranges which are beyond the boundaries of the district now referred to. Allied to this type, there is another in which hornblende occurs only to a very limited extent, being often almost entirely absent. This is a massive quartzo-felspathic gneiss, of a pale grey or buff color, and for the most part distinctly foliated. This variety is more particularly developed on the south side of the Cauvery, in the Trichinopoly district.

Syenitoid gneiss.

Quartzo-felspathic gneiss.

Quartzites, or quartzose gneiss, occur only in one or two localities, as close to Naivailie.

Quartzite.

Hornblende schist alternates very frequently with the quartzo-felspathic variety of the gneiss. Hornblende occasionally predominates to such an extent as to con-

Hornblende schists and rock.

stitute a regular hornblende-rock, in which any trace of foliation is generally most obscure, rendering the rock very like many igneous rocks. The bedded or banded structure of the mass, however, alternating as it does with the same structure in other varieties of the metamorphic series, readily determines the true nature of the rock.

Talcose schists.

Talcose schists occur in the Salem-Ahtoor valley, on the southern flank of the Godumullay, whence they trend continuously and with increasing width up the east side of the Tainandamullay hill, finally crossing the Punniar at Munnikul hill. They underlie the great Godumullay iron beds. Course quartzo-hornblendic schists, also containing talc, occur north of Huroor in the Baramahal.

Chloritic schists.

Chlorite-schists occur over much of the country between Tathengarapaittai in the extreme south-east corner of the Salem district, and Cunnanoor, in the Trichinopoly district; and among these chloritic schists, beds containing garnet in abundance occur at Tholya-nuttum and Poodooputty, in the Moosery taluq, in Trichinopoly district.

Quasi-porphyritic gneiss.

Associated with the chloritic rocks in the same district is a considerable development of a quasi-porphyritic gneiss, highly quartzose, with imperfectly formed crystals of drab, pink, or purplish felspar; these imperfect crytals disseminated in the general matrix, and frequently causing the mass at first sight to have much the appearance of a conglomerate; the foliation, however, is almost invariably well marked. A similar rock occurs at Caudputoor, a few miles north-east of the junction of the Ambrawutty with the Cauvery, and also at different localities between this and the places noted above, indicating the extension of beds of this variety across the country.

South of the Cauvery, gneiss of a similar character was observed (but not to so great an extent) at Munnicondum-choultry, 8 miles south-south-west of Trichinopoly, and again further to the west at Ramchander Trimullay. At the former of these places, the irregularly porphyritic

character of the rock is not so apparent, the felspar having become segregated, as it were, into bodies of an almond-shape, which are arranged closely and sinuously together in lines parallel to the foliation. Many of these segregated portions are binary compounds of quartz and felspar.

Such are some of the more marked varieties of the gneissose rocks in the series. But a very peculiar form of altered rock, which is quite irrespective of any general variety in the series, occurs in the Ahtoor division of the Salem district, to an extent sufficiently great to warrant our noticing it specially.

Trap-shotten gneiss.

This rock is gneiss of various kinds, altered, through more or less immediate contact with trappean rocks, to such an extent and in such a manner that it is, as it were, very largely impregnated or shot with strings of dark-green or bluish-black compact trap, and on first seeing it, the term trap-shotten gneiss immediately occurred as a very appropriate one. Where this rock occurs, the foliation of the gneissose rocks is very distinct, having generally an east by north and west by south direction, while numerous trap-dykes traverse the rocks with a north by east and south by west direction, (or generally in the north and south system of jointing,) thus crossing the lines of foliation obliquely at an angle of about 65°. The gneissose rocks have, however, been so thoroughly altered and impregnated with trap in this general north and south line, that long bands of this trap-shotten gneiss stand out boldly from the main mass of the series, and now look like (and have the same effect in giving character to the features of the country as) great dykes of some rock quite distinct from that which is adjacent. This is especially seen in a ridge of hills which have a north-north-east and south-south-west direction, to the south-east of Ahtoor, in which ridge the Munjinny and Sharooye hills are both trigonometrical survey stations. These long bands of altered gneiss, together with trap-dykes, appear to form the back bone, as it were, of the ridge. A band of this altered rock is well seen in a gorge due west of Gungavully, where an attempt has been made to form a large tank-bund. Indeed,

this band of hard rock itself seems to have once formed a very ancient bund across the gorge, backing up the waters, which formed the thick alluvial deposit lying to the west of this rocky band; but it, like the more recent artificial one, had been broken through.

b. Crystalline Limestone.—This rock is of rare occurrence in the districts under consideration, being found only at five or six places. It occurs at Naivailie on the left bank, and at Mootum on the right bank, of the Iyaur, both in the Moosery division: at and near Culputty, in the Vettycutty division: and it crosses the Madura road 16 miles to the south of Caroor; all partly or entirely in the district of Trichinopoly. It occurs also at Shattumboor, 7 miles to the south-west of Namcul, in the Salem district. In the country at the south-west corner of the map, are bands of limestone extending over a length of more than 12 miles, and stretching far into the district of Coimbatore. The Madura road is crossed by four of these at a short distance to the north of Polliam, 16 miles south of Caroor. From this point they stretch in continuous lines in an east-north-east direction to a large boss of gneiss, around which two of the limestone bands make a slight bend or curve, and then pursue their original course (although occasionally covered up and concealed by alluvium and gneiss-debris) to a point south-west of Keeranore. In addition to the three principal bands, there are others of greater or less extent and magnitude, running in the same direction, which are best seen between Kurrinculputty and Nursingaparum. A great number of small bands cross the old boundary bank between the districts of Coimbatore and Trichinopoly, but these are eventually united into thicker beds or spread out into rocky surfaces of thirty or forty yards in width, which disappear beneath the alluvial deposits of the two streams running to the north, and re-appear as a nearly equal number of beds crossing the country further to the east. Two beds also occur about 2 miles to the north-east of these at Keeranore, one of which was

Polliam beds.

traceable only for a mile or so in a continuous line. An apparent continuation of this bed was observed further to the east-north-east in a very dense scrub-jungle, but owing to the absence of any marked points, the true position of the locality could not be determined.

The limestone at Polliam is interbedded with a compact hornblendic gneiss, the foliation of which varies in direction between east-north-east and west-south-west (E. 25° N.), and north-east by east to south-west by west (E. 38° W.), while the dip is 70° to the southward. Near to Kurrinculputty, 3 miles east-north-east from Polliam, there is a boss of this gneiss, where (as will be seen on a reference to the map) the remarkable straightness of the beds of limestone is broken, a necessary widening out of these having taken place in order to fill up the vacancies caused by the crumpling of the beds of gneiss forming this boss. At the same time, the alternating beds of gneiss and limestone to the south of this do not show such a fold, but preserve the direct strike. Intrusions of granite have occurred to a limited extent to the north.

Variations in the colour and texture of the limestone in this locality are pretty frequent. Nearly pure white marble, both fine and coarse-grained, lies immediately round the south-west base of this boss of gneiss, while on the opposite side is a largely crystallized variety, in which separate crystals of carbonate of lime (Calcite) are easily distinguishable: generally of a pink colour. A beautiful pink variety, admirably adapted for marble slabs on account of its close texture and absence of folia of foreign minerals, is of frequent occurrence in several bands. East of Keeranore, there is a bluish-coloured band, and a wide spread of pale grey limestone forms a foundation for the village of Veerarlyputty, 2 miles north-east of the gneiss-boss mentioned above.

Included minerals.

Other minerals, such as Chlorite and Mica, enter more or less into the composition of most of the limestone of this part of the country, but in some beds these are very rare, and sometimes totally absent. When occurring to any extent,

they form laminæ running through the mass of the rock. Chlorite occurs largely in some of the pink limestone, dotting the surface with bright green, while glittering scales of yellow Mica replace this mineral in the white varieties of the limestone. Detached pieces of gneiss and nests of quartz sometimes occur enclosed in the limestone, but these are very rare.

Culputty beds.

A small but very interesting development of crystalline limestone occurs on the upper and now almost abandoned road from Trichinopoly to Caroor, 1¼ from the travellers' bungalow at Poodoopolliam, to the south-east, and close to the village of Culputty. It appears at a point where the quartzose gneiss has undergone considerable contortion, the strike of the folia curving round from south-east to north-north-east (E. 45° S. to E. 68° N.) in the space of a few hundred yards. There are, close to this, many small and two or three moderately-sized granite veins running north and south across the general line of strike of that locality, which is west-north-west to east-south-east. But these do not appear to have been in any way the cause of the disturbance which is observable. At this place there are three small bands of limestone running in a north and south direction across the high road, with a westerly dip of about 40°, and apparently uniting a few yards to the north of the road, when the main bed continues its course for about one hundred and fifty yards, and disappears under the surface debris, only a few yards before the gneiss beds, which are seen a little to the west, are deflected by a sudden curve to the north-east by north. (N. 32° E.)

The greatest width of the beds is shown on the road. The most easterly bed is about 12 feet wide, and this continues for about 60 paces until it joins the main bed. This main bed is about 8 feet in width and 200 yards in length; and the westerly bed, seen only on the road, is about 5 feet wide. The limestone is compact, rather fine-grained, and of white colour, sometimes with a grayish, or a

very pale and delicate greenish-blue tint. It contains here and there small masses of garnet and quartz, with prismatic crystals of a dark green mineral (Actynolite ?), varying in size from about one inch and three quarters long by one-third of an inch broad downwards. The smaller green crystals are very numerous in patches, chiefly at the sides of the bed. Isolated dodecahedrons of garnet are also to be found, and also imperfect tabular crystals of white and pink Calcite, and small masses of Chlorite.* Scattered over the ground near the beds of limestone, there was much debris derived from it and from some of the adjoining granite veins; and among this debris several very fine pieces of compact garnet rock, and some specimens of quartz, containing large but imperfect crystals of black and green hornblende.

Elanoothoomungalum bed.

A little more than 2 miles to the north-west of these limestones at Culputty, another small bed is exposed close to the south side of the road, and only a few hundred yards to the west of the village of Elanoothoomungalum. About 50 yards in length of this bed are uncovered. It shows faint foliation heading to east-south-east, with a distinct dip of 85° to N. N. E. The bed is about a yard thick, and consists of very pure pale greenish-grey saccharoid limestone, without any associated minerals. It is impossible to say whether there be any connection between this apparently isolated bed and those at or near Culputty, the whole country being much covered up by debris and by soils, especially near to Elanoothoomungalum.

Beds north of the Cauvery.

North of the river Cauvery, beds of crystalline limestone occur in several places, namely, at Shatumboor, near Namcul, and at Mootum, west of the Iyaur river; near

* A few feet from the northern end of the limestone beds lay some loose blocks of a very dark impure limestone, throughout which are distributed many of the dark green crystals. In a fragment of this dark purplish-grey rock, a speck of a metallic mineral, apparently Copper-pyrites, was found, but no further traces of any metal were observed.

Naivailie, 16 miles to the north-west of Trichinopoly; also at Thutchumcoorchy,* 2 miles north-east of Culpolliam, on the Trichinopoly and Madras Road.

Mootum beds.

At Mootum the rock is only seen for about a mile along the surface, as a bed of 10 feet in width, striking east-south-east, and having a dip of 45° to the N. N. E. It is covered up by the alluvium at its eastern end, and crops out to the west. The stone is generally of a pink colour, and varies much in its texture. To the north and to the south of this, granite veins are very numerous, but there is no gneiss visible close at hand, similar to that which is associated with the limestone at Polliam.

Naivailie beds.

At Naivailie,† limestone crops out between beds of quartzite and hornblendic gneiss, which strike to east-north-east. To the east of the tank there is a spread of alluvial soil, under which the limestone disappears, but it is again seen in the same direction for a short distance, when, together with the beds of the gneiss, it turns up to the east-north-east, apparently in consequence of the intrusion of a great mass of granite to the south. After maintaining the latter course for some distance, the band of limestones bifurcates, and encloses a large boss of hornblendic gneiss, beyond which one of the arms of the divided band spreads out into a slightly furrowed surface, some 50 yards in width. It then narrows again, and ultimately joins another thin band coming from the north side of Naivailie village: after the junction, it decreases its width, and about one mile to the eastward, it dies out. Throughout this course the beds are vertical.

The different colours of this limestone are nearly the same as those seen south of Caroor, and there are the same differences in the texture and the stone, excepting that the very coarse variety which we have

* Memoirs of the Geological Survey of India, Vol. IV, Part 1, p. 204.

† A notice of these beds by Mr. King was published in the Madras Journal of Literature and Science, Vol. XXI, p. 272, 1859.

noticed at Caroor does not occur here. The foliation is very distinct, some of the folia being of gneiss, or chlorite, or mica, which contrast strongly with the paler coloured limestone. Small detached portions of gneiss, granitoid gneiss, and nests of quartz and calcite are sometimes observed enclosed in the limestone.

The limestone in this locality, as will be seen, offers some points of analogy with that of Polliam in the character of the associated rocks; in both cases there are beds of hornblendic gneiss, curving abruptly at certain points. At Naivailie, however, the foliation is contorted, and many of the laminæ are broken in continuity, those of the felspar and quartz assuming an irregular lenticular shape; while at Polliam and its neighbourhood the foliation of the gneiss is perfectly straight and continuous. Beds of quartzose-gneiss also occur north and south of the limestone in each locality, and small intrusions of granite have taken place.

Great anticlinal fold.

We believe that the limestone at these two localities forms part of a great fold of the metamorphic strata,—a supposition strengthened by the existence of the great anticlinal uxis mentioned above, and by the similarity of peculiar beds on either side of the quartzo-felspathic nucleus. In this way the band of gneiss extending with few interruptions from Caudputtoor to Thandalay (Thandala) corresponds to a band of the same kind of rock occurring at Ramchunder, Trimullay, and Munnikaudan Chuttrum. The hornblendic gneiss associated with the limestone also corresponds in the two localities.

Although the limestone occurs so largely in the south-west part of the area we are describing, close to many villages, some of which are even built upon the wider expanses of the rock, it does not appear to have been used in any way by the people, excepting as a stone on which to sharpen their knives and hatchets. They prefer the more stubborn gneiss as a building stone for their temples, and the more readily collected

little fragments of *kunkur* for lime. They admit the superiority of the stone-lime, but say that a basketful of the ordinary kind is quite good enough for their work.* At Naivailie, fine masses of limestone have been quarried, but for no other purpose than to enable the workmen to get more easily at the bed of quartzite which is adjacent on the northern side.† The limestone, however, is undoubtedly a valuable material, and might with advantage be used when obtainable in sufficient quantity. As a material for building, it is lighter than any of the gneiss rocks, and the finer varieties are not exceeded in durability by any of these. The limestone at Polliam is most conveniently situated for quarrying, being close to the high road, and blocks adapted either for ornamental or ordinary building purposes would be easily obtainable from any of the bands we have noticed above. Naivailie, again, is only 7 miles from the Cauvery, down which river the stone could be carried in boats to Trichinopoly or into the Tanjore district. Indeed, during the freshes in the river, the stone could be loaded close to Naivailie, where the Iyaur passes the village.

Economic value of limestone.

The beds of limestone at Culputty, although small, will prove highly valuable if the line of Railway from Trichinopoly to Errode be carried out, being close to the probable track of the line.

There can be little difficulty in recognizing the limestone rock in the places we have alluded to. Near Polliam, it occurs just above the surface of the ground, in long straight bands varying from 1 to 20 yards in width, of smoothly weathered light grey rock between projecting slabs, and ridge-like masses of a brownish-grey gneiss. The latter is always hard and gritty to the touch, while the limestone has a dull roughness; the ring from a blow of the hammer is nearly as different, being sharp in

* The superiority of the stone-lime is chiefly in colour, and for some purposes only. Much of the kunkur yields an admirable hydraulic lime.

† See Chapter on Economic Geology.

one case, and dull in the other. The vegetation on the two kinds of rock is also peculiar, a thorny jungle growing for the most part along these stony paths (for they are used as such), while on either side of them are barren sandy fields. When the beds cross the Madura road, they may easily be distinguished, for white ruts have been worn across them by the wheels of the passing carts, whereas no such marks have been made on the harder gneiss adjoining.

c. The Magnetic Iron Beds.—Of the many rock varieties constituting together the great gneissic or metamorphic (or azoic) region forming the main mass of the southern part of Peninsular India, none are more striking in appearance, or more important as a source of mineral wealth, than the splendid beds of magnetic iron ore (Oxydulous Iron or Magnetite of mineralogists), which are dispersed over the western half of the gneissic region described in this report. To the Geologist they are further of great interest and value, as they, more than any of the other strata, enable him to decipher the great contortions and flexures which have tended in great measure to produce the existing form of surface in these regions. The number of these beds met with during the progress of the survey is so considerable, and they resemble each other so much in their main features, that it would be unnecessary to give a separate account of each individual bed; but a list showing their position, extent, and relation, may not be out of place, while a detailed description of two or three of the richest and most remarkable will be sufficient for all practical purposes. The list given must not, however, be considered as an exhaustive one, for many of the beds in question are known to extend far beyond the limits of our area, especially to the northward. These will form the subject of investigation as the survey is extended over the northern parts of the Salem and South Arcot districts. How far they may extend to the west and south has also to be ascertained. A brief notice of one of the most important series of these beds lying near to Salem, but just beyond the western limit of our area, the well

known Kunjamullay beds, will be added as an appendix. No magnetic iron beds were noticed south of the Cauvery, nor to the east of the meridian of 79° 10′ east longitude.

The iron beds which are most important in extent and richness lying within our area are those belonging to the four following groups:—

1st.—The Godumullay group, east and north-east of Salem.

2nd.—The Tullamullay-Kolymullay group.

3rd.—The Singiputty group.

4th.—The Tirtamullay group.

Godumullay series.

The *Godumullay group* consists of two great parallel beds running from a spot about 9 miles east by north of Salem, along the ridge of the Godumullay; it crosses the Vellaur river at Valoor, and runs along the ridge of the Valoor hill. The exact course of the out-crop then becomes obscure, owing to thick jungle and debris of other rocks occupying higher positions; but about 2½ or 3 miles to the north-east, another smaller and poorer iron bed appears in such a position that it must be considered the continuation of the lost beds. This bed is distinctly traceable up a long spur of the Neighemullay (pronounced Nayaymullay) to the village of that name, on the east side of which two large and rather rich beds form the edge of the plateau; where the ground falls at the north-eastern end of the small plateau, the two beds are hidden by thick jungle, but they re-appear about 1½ mile to the north-east at the village of Manoor, and in less than a mile to the north, are again hidden by thick jungle. They do not re-appear in the Tandumputty valley, being doubtless hidden under the thick accumulations of soil; but 3 miles to the north of the last named village, close to a small Mullayali hamlet called Vulshay (Valassy), several beds of good ore show on the very steep slope of the hills, but are not sufficiently exposed to enable one to judge of their size. North of Vulshay these beds are again lost

Neighemullay.

Vulshay beds.

sight of, but may perhaps be again recognized at a distance of 12 miles on the north bank of the Punniar river, in a large bed of fine magnetic iron, occurring about a mile east of Mondacooly. Its course to the north-east by north is, at a distance of about one-half or three-fourths of a mile from the river, obscured by overlying soil, but there can be no doubt the bed might be discovered again further north, and also that the great gaps between Manoor and Vulshay, and again between Vulshay and Mondacooly, might be, in great measure, if not entirely, filled up, if time could be spared to follow up the out-crops through the pathless and often almost impenetrable jungle covering the flanks of the Tainanda- and Carapaudy-Mullays. This would not, however, be a very profitable task; it would require several days' work in very unhealthy forests, and there can be little doubt of the continuation of the iron beds, for all along the eastern side of the Tainandamullay, we find the continuation of a great thickness of talcose gneiss beds, which stretch away past Cottaputty and Vyroonaickenputty to the banks of the Punniar, cross that river, and pass beyond the limits of the map. A few remarks on the position occupied by this Godumullay series, on and around the Godumullay itself, may not be uninteresting.

Mondacooly bed.

The Godumullay is a very fine bold mass, rising between 1,200 and 1,500 feet or more above the centre of the great Salem and Ahtoor valley, and forming part of the water-shed between the hydrological basins of the Cauvery on the west and the Vellaur on the east of pass. The Godumullay is about 4 miles long from west to east, which is very nearly the direction of the axial ridge of the mass; its extreme width at the eastern end, where broadest, is about 3 miles, including the north and south spurs of the hill. The Spanish name of Sierra (a saw) would be particularly applicable to describe the side view of the ridge, especially when seen from the south. This serrated ridge consists of the chief bed of magnetic iron which runs

Godumullay hills.

up it, gradually increasing in elevation from west to east till it reaches the summit at the eastern extremity of the ridge, marked by a cairn erected by the Trigonometrical Surveyors. On the northern side of the summit there is a splendid precipice, several hundred feet high, overhanging in several places. (See Plate 1.) The bed is here shown in great magnitude, forming the whole summit. At the western part of the ridge, just below the high crest, the quality of the magnetic iron is very rich, and much iron sand is collected from the southern talus to supply the Ollays, or small native furnaces in several of the neighbouring villages. At the eastern end of the Godumullay, on the contrary, the bed is very much poorer in iron.*

Great precipices of iron beds.

It is at the western end of the ridge that the normal position of the main beds may best be studied by ascending the saddle which cuts deeply into the ridge to the north-east of Maituputty. The bed there strikes east by north with a high dip to the north by west, and is much broken up by strong north and south and west-north-west joints. The bed here consists of nothing but magnetic iron interlaminated with quartz rocks,† the former predominating greatly and forming between three-fourths and five-sixths of the mass. The same degree of richness appears to continue pretty constantly for a mile to the west, and as far as the summit of the hill to the east, after which there is a gradual diminution in the proportion of magnetic iron

Variability of ore.

* This iron bed may possibly be a continuation of the northern bed, which is lost sight of on the flanks of the western end of the ridge, about 1½ mile from Natamungalum (Sircar Nauta of map), in which case the great summit bed must be regarded as completely hidden under the debris covering the eastern slope of the Godumullay, or to have died out suddenly. The break apparent between the summit and the re-appearance of the magnetic iron at the north-east foot of the hill is probably the result of denudation at the apex of a small sharp bend, similar to one clearly shown on the low outlying ridge, a little to the north of the high road, and about 3 miles west of Walapaudy.

† An imperfect crystallization of the magnetic iron has, in many parts, both in these and other iron beds, resulted in giving the iron laminæ a granular and stringy appearance.

to about one-fourth of the mass. To the east, however, the bed when ascending the Valoor hill, again becomes richer, and shows a very fine ore containing about three-fifths of the pure magnetite. It then again becomes very poor, but shows a fine rich ore on the Neighemullay plateau.

Travelling by the high road from Cuddalore to Salem, one could not fail to be struck with the very fine bold rocks rising from the ridge of the Godumullay, especially about three-fourths of a mile west from the summit. At this spot there is a gigantic naked rock, part of the magnetic iron bed, rising between 3 and 400 feet almost vertically above the ridge. Between it and the summit is another bold peak, but of much smaller dimensions, and not so lofty. As you ascend from this intermediate peak to the summit, past a banian tree sacred to Permal, the view, looking back towards the west, is perfectly glorious. In front are the two peaks just described, showing their bold outlines to great advantage, and fascinating the eye by the striking colours due to their mineral composition. To the right and in the centre the back ground of this magnificent view is formed by the forest-clad Shevaroys; to the left by the distant Palamullay, a fine mountain mass west of the Cauvery in Coimbatore district. Where the rocks are unbroken, but where blocks have fallen away and the weathered joint surfaces appear, the deep purple of the mass is varied by shades of red so bright as, when illuminated by the sun, to almost rival vermillion in its intensity. The summit rocks of the great peak especially are in addition much covered with a white lichen, which by contrast greatly enhances the beauty of the other colours.

The great precipice on the north side of the summit presents the same vivid shades of red, toned by streaks of brown, and offers altogether a very grand yet singular appearance contrasted with the bright green of the forest, in a great ravine several hundred feet below the summit, the only piece of true forest that has been left remaining on the hill. The thickness of this great bed varies a little, but averages probably between 50 and 100 feet; the generally broken condition of the out-crop,

and the immense talus resulting in consequence, renders it very difficult to find a spot where it is practicable to measure the width of the outcrop. The northern or Natamungalum (Sircar Nauta) bed is near that village of good quality, but not so rich as the main ridge bed, which seems quite equal to the very richest parts of the finest beds of the Kunjamullay and of the Tullamullay-Kolymullay series in the Rajahpooram (Ranzepoor) Talook.

The highly magnetic nature of the rock renders it very difficult, in many cases, to get a correct idea of the course of the beds if they are situated in thick jungle, unless there be some very decided landmark by which to work, as the compass becomes utterly useless near the beds. Several of the beds met with had to be laid down merely with regard to the general configuration of the country. This difficulty was experienced several times in tracing the connection between the iron beds of the Valoor hill and the Neighemullay, and the positions assigned on the map to the intermediate parts can only be regarded as approximately true, the map itself being deficient in that accuracy of detail in its topography which would enable the beds to be carefully laid down. The general direction of the strata all over the area under report, namely, a trending from west-east to south-south-west, north-north-east, is very well shown in the course of these iron beds, running, as they do, from along the curves of the Tainandamullay range.

Tullamullay-Kolymullay series.

2nd. *The Tullamullay-Kolymullay group of beds.*—This group figures very conspicuously in a vast curve formed in the southern part of Salem district by a very large number of the strata constituting the gneissic system. It will be seen, on referring to the map, that this great curve is not altogether included in the map, the western and apical part of the curve lying beyond the limits of our report, and not having, for that reason, been followed up and mapped. There is no doubt of the existence of the curve of the lowermost beds, and the curving of many of those overlying the

iron beds is remarkably perfect, especially some of the numerous hornblendic beds to the east of Namkul. The great curve, or rather series of curves, is due to a peculiar elevation of the strata, which were then planed down partially by some gigantic denuding agency, acting through periods of immense duration. The total thickness of strata which appear in this great curve, measuring from the south side, on which the succession is most clearly displayed, to the centre of the Kolymullays, where the *heart* of the curve appears to be, must be very great. The angle of dip may safely be assumed on the average to be 60°, the angles taken at three of the most prominent points on the periphery of the curve being 65°, and the beds in many parts dipping at angles as high as 75°. A section from north to south across the Tullamullay, and continued across the Kolymullays, would cut across one or more of the curved beds occupying a very high place in the whole series, and show very nearly if not the entire number of beds. This section, extending from a point about 2 miles east of Totium to the magnetic iron bed north of Wallalputty, on the Kolymullays, a distance of 18 miles, in a direct line across the out-crops of parallel strata dipping north at an angle of 60°, would represent a thickness of some 50 to 55,000 feet of solid rock, or, if a liberal allowance is made for undue attenuation of the strata owing to a sliding movement against each other, the thickness may safely be taken as varying from 40 to 45,000 feet. This must not of course be considered as the thickness of the whole series of metamorphic rocks, but only of that portion of the beds forming the series included in this giant curve.

Estimate of thickness of section.

The number of iron beds belonging to this series may be set down as three, though really there are several more, but these latter are shown to a very small extent, and are probably not continuous, but die out very soon after they become obscured by the overlying soil. The principal beds

Principal iron beds of series.

occur about half way up through the series, and have been traced from a little north of Thathensarapetta (Thathengarpaittai of map), westward to the most northerly ridge, outlying from the Tullamullay and all along that ridge. Westward thence they form two well marked wall-like ridges, which disappear a short way east of the alluvium of the Karavetaur to re-appear on the west side, and finally range beyond the limits of the map to the south of Keerumboor, 6 miles west-south-west from Namkul. The apex of the curve is, as before mentioned, not included within Sheet 79, but there can be no doubt that the beds corresponding with them are those appearing at Vellakaputty, and running thence with a southerly dip to the north-east by east. They appear in force just west of the Salem and Trichinopoly road, and again about a mile to the east. At a distance of about 4 miles from the road, the bed ascends a conspicuous ridge, and keeps along the crest of it for several miles, till cut off by a great trap-dyke, and apparently faulted with a great dislocation to the north. The shift appears to amount to nearly 2 miles, but it would be hardly possible to judge fairly of the extent of the shift without renewed and very careful examination; the ground intervening between the two portions of the iron bed being covered by a great flat of paddy cultivation and a large tank, which effectually conceal the rocks at the most important spot. The eastern extremity of the dislocated portion runs up the most north-westerly spur of the Kolymullays, and is finally lost sight of in the jungle covering the flanks of the great northern spur of the Kolymullays.

Inner series of beds.

Within this great curve is another important set of beds, which appear, however, only for a comparatively short distance, in the southern area of the curves; on the north side, on the contrary, they are largely developed. To the south of Namkul they appear on the eastern and northern flanks of the Kunnavaputty Hill,* thence they may be traced in the direction of Keerumboor, to the south of which place they pass beyond the limits of the

* This hill is not named in the map, though indicated as a Trigonometrical-station.

map-area now under description. These beds lie about 1¼ miles north of the first series just described, and perfectly parallel with them. On the northern side of the curve the inner series runs from near Ullalapooram in a north-east by east direction as a fine ridge, showing two large and rich beds dipping south at an angle of 65°. These beds pass up the west spur of the Neinalmullay, and come within the limits of the great fault just described as shifting the first series. The second series does not appear to have been so much shifted, but has had its dip altered to the north. It runs up the Kolymullays to the east, and may in all probability be regarded as the bed of magnetic iron of the Pylum ridge, which divides the northern basin of the Kolymullay plateau from the Yeddapilly basin. It is by no means improbable that some connection may also subsist between this Pylum ridge iron bed and those at Tummumputty in the Ahtoor Talook, for, although the distance is considerable between these two places, the general structure of the country seems to indicate that the beds of the great curve are continued eastward into the mass of the Pythoormullay and of the Patchamullays, between which are situated the Tummumputty magnetic iron strata.

Pylum ridge beds.

It is from the great ridge west of the fault before described that the iron sand is obtained for use in the very numerous native iron furnaces at Ramagherrypetta and other villages in the Rajahpoor Talook. The iron bed there is very rich, nearly equal to the very richest parts of the Godumullay and Kunjamullay series, and the iron obtained from it is held in very high estimation, perhaps, indeed, the very highest of all manufactured in Salem district.

Included in the series of rocks exposed along the line of section, and nearly the very highest members of the series, are two iron beds occurring on the east side of Vaulavandy ridge, on the Kolymullay,—the ridge which divides the western from the great central basin of the plateau. These are exposed to a limited

Vaulavandy beds.

extent in the thick jungles, are of fair richness, and show here and there a considerable degree of decomposition into a lateritic peroxide.

Mahdavy hill beds.

Within the area of the great curve, but standing in very obscure relation to it, is a large and strangely contorted bed of magnetic iron, to be adverted to presently as forming part of the Mahdavy (Mahadevi) hill lying in the eastern part of the valley which divides the Kolymullays from Tullamullay and its subsidiary ridges. The iron bed is only moderately rich, the quantity of iron probably not exceeding one-third of the mass of the bed, the remainder being impure quartz, and here, as at Vaulavandy, the surface of the out-crop shows much lateritic peroxide formed by weathering. The south-eastern end of the double curve formed by this iron bed is lost under the superficial soil a few hundred yards east from the Pagoda or Mahadevi hill. The north-eastern, or Lutchmepolliam end of the bed, is probably continued below the surface beyond that village and towards Reddiputty, as the ground west of the Reddiputty tank is thickly strewed with weathered fragments of the iron ore, though none was met with *in situ* between the two villages in question.

Singipooram series.

3*rd*. *The Singipooram group of beds*.—The beds forming this group occupy a position about 4 miles south of the Godumullay peak. They appear to form a synclinal fold, having, if followed from west to east along the strike from Vullalacondam, a course varying from west and east to north-east by east and then trending to east-north-east and east by north. In length they extend for about 10 miles.

Number of beds.

There are three principal beds, separated from each other by intervening beds of hornblendic and quartzo-felspathic gneiss of very considerable thickness. By far the greatest visible development of the beds is along the northern side of the synclinal fold, the greatest length of which is stated above. On the south side the three beds were traced only for much shorter distances to the

west of the village of Singipooram. At Singipooram five beds of iron ore appear on the western slope of the small hill, bearing the same name as the village; only three of these appear to the west on the slope of Ponnaromputty hill, and here two are apparently cut off by a fault, the line of which is occupied by a small trap-dyke, having a north-north-east course. To the east of the village the iron beds are almost immediately lost sight of under thick soil, and do not re-appear again, while the beds on the northern out-crop die away gradually, both in size and richness, and disappear on crossing the Vellaur river a mile and a half to the south-west of Yaetapoor pagoda. Indications of magnetic iron beds are met with in the great spur of the Kalroyenmullay, north of Yaetapoor, and are in all probability representatives of this Singipooram series. In point of richness the beds of this series are not very remarkable, the richest being part of the northern or lowest bed lying south-south-east of Walapaudy bungalow. The thickness of the bed cannot be less than 50 feet, which may probably represent the general thickness of the three beds cropping out on the north side of the synclinal fold. To this series belongs in all probability a small bed of magnetic iron occurring on the flank of Kalroyenmullay, rather more than a mile south of Toombul. Of the possible relation subsisting between this series and the Godumullay series, we shall speak further on.

Walapaudy bed.

4*th.* The *Teertamullay* Group* consists only of two great beds running parallel and close together along the crest of the Teertamullay ridge. They form also the peak of the Teertamullay, which is a very fine and almost isolated mountain mass, about 8 miles north-east by east of Huroor. To the east the side of the magnetic iron bed forms a tremendous and apparently perpendicular precipice of many hundred feet in height, which gives the peak a very fine bold outline when seen from any position except from the east or west. This

Teertamullay series.

Cliffs of iron ore.

* Erroneously called the Teerleemullay on the Atlas sheet.

great precipice, like those of the Godumullay, shows many fine tints of purple, red, orange, and brown, which show out very well under the rays of the morning or mid-day sun: the iron mass generally is of a fine brownish or greyish-purple colour. Close to the well-known temple of Teertamullay, standing at the foot of the mountain on the north-west side, the beds may be easily examined to great advantage on the northern spur; they there show a dip of 82° to the west. The two beds are continued northward as well-marked ridges, and extend beyond the limits of our area. They are probably continued into the Ammapettah hill, and prolonged thence for a considerable distance north towards the Javadie hills. To the south of the Teertamullay the beds are lost in the jungle under thick soil at about a mile and a half south-south-west of the peak. The beds near the pagoda are of very rich quality, and seem to have been extensively worked, if we may use such an expression with reference to the numerous holes and burrows made in extracting the iron sand from the decaying masses of the talus.

The iron made from this ore is also held in high estimation. The supply of ore here also is unlimited, the beds being of great thickness (probably between 50 and 100 feet each, and possibly a great deal more); no accurate measurement or estimate could be obtained at Teertamullay pagoda where best seen, because of the broken state of the out-crop and the great talus.

Bed in Taultooky ravine.

As belonging to the Teertamullay group, we may with some probability regard a bed of magnetic iron exposed in the great ravine running south from Taultooky to the slopes of the Tainandamullay. The bed is exposed only for a few yards on the north-west spur of the Shedayry peak (Chittairy), but its course would in all probability be traceable, if the adjoining dense jungle were searched.

Relative age of this series.

The Teertamullay series is in all probability of much younger date than the Godumullay series, but the actual superposition of the former over the latter series cannot

as yet be considered as an established fact, many of the intermediate out-crops having an apparently vertical dip, which renders it a matter of great difficulty, and indeed of impossibility, to assign them their true positions, except by a large series of very minute observations. This is readily to be understood if the vast extent of the forests covering these mountain ranges be taken into consideration, in addition to the fact of the extensive alteration of character and the great and wide-spread contortions of these metamorphic rocks.

Of the other beds of magnetic iron met with in various parts of our area, none demand any very special notice. They are, therefore, merely included in the following list with a few remarks as to their mode of occurrence.

The order in which they are given is that in which they would be met with in travelling east from the Teertamullay as far as the road from Manalurpett to Trinomallee, then turning south and passing along the Kalroyen range southward to the Patchamullays, and then westward by the north end of the Kolymullays into the Rajapooram Talook.

No magnetic iron was met with in the area north-west of a line drawn from the Chalk hills round the southern slope of the Shervaroyen-mullay, and up the Munjawaddy Pass, past Huroor, to the northern boundary of the country already surveyed. The following list then includes the less important beds of magnetic iron :—

List of less important beds of iron-ore.

1. North-east by north of Pemaraputty.
2. North-east of Naringypaudy (indicated only by unrolled debris).
3. About a mile south of Warrioor hill (Trigonometrical station).
4. On the south bank of the Punniar river (Panar river of map) half a mile east of Porasaputtoo.

Probably one and the same bed.

5. Between Pompurapy and the great tank at Paukum.

6. Two miles north of Pompurapy. This is in all probability the continuation of a bed which appears

7. about 2 miles west of the village of Veraunganney, 3 miles south of Ravetnelloor hill, and which is traceable on the south side of the mouth of the great Toombay valley. It is worked for iron sand at Palayputty.

8. Is an under-lying bed, having a nearly parallel course at a distance of 2 miles to the south. Close to the village of Sangraveram* it makes a sharp turn to the north and becomes hidden under a spread of paddy cultivation, but appears again apparently in the jungly ridge south of Andipaleiyam. Bed No. 5 is very possibly nothing more than a still more north-easterly part of the same bed.

9. About a mile and a half south of the last named iron bed (of Sangraveram) is another bed of larger dimensions, having a parallel course, but dipping to the south instead of the north, at an angle of from 65° to 75°. The most northerly extension of this bed is probably a bed showing itself about one mile south of Paukum tank, the junction of the two parts being further indicated by a short out-crop of magnetic iron occurring at the north end of a tank near Pandalum. The main portion of the bed rises into a fine hill south of Pookanum tank. It also forms the main ridge of two other hills of much smaller size between the villages of Shellanputtoo and Yaretevanatum, and is lost sight of to the south of the latter village. No connection could be traced between this bed and some others of similar character on the south-east part of the Kalroyenmullays.

10. Rather more than a mile south of the Pookanum bed is another of very poor quality, and note-worthy only because of its relation with the three last described. At its western extremity, close to the village of Curdy Chittoor, it makes a curious horse-shoe curve and is

* Mis-spelt Sangraicram on map.

mineralogically remarkable because of the presence of specks of a gold-coloured mineral (Bronzite?) very like hornblende in appearance and lustre, and causing the rock to assume a very brown appearance on weathering. West of the village no traces of the iron bed were met with, and it is most probable that the bed dies out or loses its magnetic iron, and with it its individual and recognizable character. The four beds just described (Nos. 7, 8, 9, and 10) appear to be the remains of a great anticlinal fold, the crest of which has been denuded away; and this fold was also no doubt one of the great series of folds into which the whole series of rocks of the metamorphic regions seems to have been contorted.

11. At the extreme south-east corner of the Kalroyenmullay is a good sized and rather rich bed of iron ore on the lower part of the slopes south-east of Chinna Tripeddy pagoda. This bed, which supplies ore for a few furnaces at Devenoor (Deolnur of Map) may reasonably be regarded as belonging to the above series, and as forming a synclinal axis with the Pookanum bed (No. 9), although the north-east extension of the bed is soon lost sight of under soil after leaving the foot of the slopes.

Beds on the Kalroyenmullay.

On the Kalroyenmullays many beds of iron ore are met with, but they are as a rule visible only for short distances, on account of the thick bamboo or tree jungle covering the ridges and valleys of the plateau. It would hardly repay the great toil necessary to follow up these beds through the jungles, as far more important iron beds are so much more conveniently situated in the low country, as the Godumullay and Teertamullay, and above all (though not within our area of report) the Kunjamullay, along the base of which the railway from Salem to Beypoor runs for several miles.

The beds observed on the Kalroyenmullay occur at the following places:—

12. On the ridge west of Purkumchairy, at the northern extremity of the range about half a mile to the north, is a very bold crag towering

high up over a fine peak and presenting to the eye an appearance very much like that of some of the smaller peaks of the Godumullay ridge. This crag, which bears the name of Palicontra Swamy Mullay, may very likely be a continuation of the bed in question, but there was no opportunity of examining it.

13. Two miles east of the last a small bed of fair quality crosses the main stream of the Purkumchairy valley.

14. A little more than a mile north-east of Innaud is a rather poor bed.

15. A few hundred yards east of Pellapoondee a fine bed of rather rich ore is exposed on the flanks of a hill rising high over that village.

16. Two fine beds of rich ore occur in dense jungle on the west flank of the Great Moodoor hill. One or other of these in all probability represents the great Pookanum hill bed.

17. A little more than a mile south of Moodoor hill, the village of Coveyeth stands on the northern slope of a hill, the crest of which is formed by a large bed of magnetic iron ore.

18. A small bed occurs in the valley north of Yaelloor, about 2 miles south-east from the foregoing.

19. Two small beds occur at the foot of the western slope of the Aviarmullay (Trigonometrical-station).

Beds south of the Vellaur.

South of the Vellaur a small but rich bed included in the series exposed in the remarkable curve of the Mulliakerra hill (Trigonometrical-station).

20. A connection may probably exist between the foregoing and two poorer beds running for a couple of miles west from Arriapolliam, a village distant about a mile from the north-west spur of Mulliakerra hill.

21. Two good beds occur on a great hill north-west of Pythoor :—

22. And at the southern foot of the Ahtoor hill, whence the very numerous furnaces in blast at that important village are supplied with iron sand.

On the Patchamullays.

23. *On the Patchamullays.*—A very large and generally rich bed stretches across part of the southern margin of the Tholoor or southern section of these hills, the outline of which, looking to the south, is mainly due to the strike of the strata, and agrees with it very nearly. The bed descends into the low country near the saddle which divides the Essany hill (Trigonometrical-station) from the main mass of the Patchamullays; its course is then lost sight of.

24. A good sized bed of poor ore runs along the ridge of the Ellumbaloor hill, a very conspicuous hill west of the Trichinopoly and Madras road, between Volcondapuram and Torramungalum. The masses exposed in the talus on the northern side of the hill are so much rounded, as to suggest their having undergone the grinding action of a heavy surf.

25. Another large and generally rather rich bed occurs, crossing several of the outlying hills and ridges south-east of the Patchamullays.

It crosses the Sandapooram hill from west to east, thence proceeds to the ridge between the Sandapooram valley and the Keela Kanavoy Pass.* At the village of that name the bed makes a sudden bend to the south and runs up the north spur of the Chuttramanny hill.

The relative positions of the strata of the southern part of the Patchamullays are most obscure, owing to the great contortion and probably also fracture which they have undergone. It would therefore be hazardous to venture on any speculation as to which of the great iron beds of the Tullamullay and Kolymullay series they may represent, though an elaborate survey on a more extended scale would in all probability establish some such connection.

Between the northern flanks of the Patchamullays and Salem are several other beds to be enumerated.

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* The Tamil word "Kanavoy or Kanava" signifies a pass between hills.

26. The iron beds of Tummumputty and Chindhariputty already alluded to (see page 65).—These are very rich at the western extremity of their visible course, but become poor towards the east, and appear to die out in the east and west ridge lying to the north of Vetticaud.

Tummumputty beds.

27. An iron bed occurs on the hill north of the Swaida Aur river and opposite Conariputty. These two sources (26 and 27) supply the iron sand for the numerous furnaces at Tummumputty and in several of the adjoining villages.

Both at Chindhariputty and Tummumputty the iron stone has been largely employed in the building of tank bunds and other coarse masonry.

28. About 7 miles north-west of Tummumputty, and 1 mile south of Shindalingy, and again about a mile south of Orumbur, are iron beds, probably parts of one and the same bed. Their quality is rather poor.

29. A small bed on the ridge north of Shindalingy.

30. On the top of Keddamullay, about three quarters of a mile east of the village of that name, is a rather poor bed.

31. A small bed of rather rich quality close to the southern base of Keddamullay.

32. About 2 miles north-east of Rajapooram (Ransepooram) is a curious horse-shoe curve, formed by a bed of poor iron stone, bending as it were round a low hill. The ore is of bad quality and associated with numerous crystals of coarse garnet and of the gold coloured hornblende-like mineral described as occurring in the Curdy Chittoor iron bed No. 10.

33. Four miles south of Rajapooram is a low ridge running along the north bank of the river which drains the country between the Kolymullays and Boadthamullay. This low ridge, which extends for about 2 miles, consists in great part of a very poor bed of iron stone, abounding like the last in garnets in dodecahedrons. To the west it does not appear to cross the Salem road, while to the east it re-appears after a

break in a very low ridge, to die away under the alluvial flats opposite to Singilandapooram.

Original source of iron unknown.

As to the source whence came all these immense quantities of iron, which in the form of magnetic oxide associated with quartz laminæ constitutes the numerous vast beds we have been describing, no conclusion can be formed.

Quantity available.

The quantity of extremely rich iron ore available from the various sources named for smelting purposes may be stated to be inexhaustible. Great part is obtainable by the very rudest methods of quarrying the surface; indeed, mining would not be necessary for a very long time. If regular mining be adopted, many thousands of millions of tons of ore are at command. Nothing, therefore, but the want of fuel will prevent this part of India from being capable of supplying the world with a never-failing quantity of the very best iron.

The method of smelting the rich magnetic iron sand adopted by the natives will be briefly treated separately in an Appendix, and a lengthy account is given in the catalogue of the Government Central Museum at Madras, compiled by Mr. Edward Balfour, of the Madras Medical Service, when in charge of that establishment.

Magnetic currents in iron beds.

With regard to the nature of the magnetic currents which occur in these great store-houses of magnetism, but little can be said, as they were found to vary much within very short limits, and would consequently have required a much greater expenditure of time than appeared warrantable to devote to a great number of observations, in the absence of delicate instruments. When brought well within the influence of the currents, the needle generally oscillated violently, frequently rotating three or four times before the perturbation lessened, when the needle generally settled with the north pole deflected more or less eastward, and often *coinciding with the strike of the iron bed.* In detached blocks, even at some distances from

the bed, the current frequently deflected the needle till it became parallel with the *laminæ of the mass,* whatever their direction happened to be.

(d.) Granitoid Gneiss of South Arcot.—In the central part of the South Arcot district, a very considerable area is occupied by rocks having generally a very granitic aspect, yet showing in many places undoubted stratification, especially in their mode of occurrence, as great continuous ridges which may be traced for many miles, and which form apparently anticlinal and synclinal folds.

Extent.

These granitoid rocks extend from a little west of Tiagar-Droog hill south-eastward to the Trichinopoly and Madras road, which they follow in a north-easterly direction to the alluvium of the Guddalum and Punniar rivers. They re-appear on the left or north bank of the latter river, and continue their course till they pass beyond the limits of our area. The western limit of this granitoid gneiss series may be traced from near Tiagar-Droog northward, along the eastern side of the road to Manaturpett, on the banks of the Punniar river. A line continued thence through the villages of Walliputty and Tandri to beyond the limits of the map, would roughly indicate the western limit of the pseudo-granitic rocks. The relation of these rocks to the other members of the gneissic series is very doubtful and obscure,

Relation of position.

not one single satisfactory case of contact and juxta-position having been met with around the limits of the large area described above, as including these granitoid gneiss rocks.

Metamorphic origin.

In the absence of any satisfactory sections, the general position of this granitoid area seems to point to the fact of these rocks overlying, or being younger than, for example, the iron beds of Paukum and Curdychittoor to the west, or than the quartzo-felspathic strata forming the great curves of Agraram Kotallum Trigonometrical-station hill. Should this not be a correct view of the position of these curiously granite-like gneiss beds, the only expla-

nation that seems to offer itself is that the area over which these beds are found was subjected to an amount of metamorphism greater than that which has affected the adjoining portions, probably in consequence of the greater or more continued proximity of some vast quantity of plutonic rock as granite or syenite, and that thereby the beds, which must be regarded as part of the general series of metamorphic rocks in that region, were in part (and especially the more felspathic varieties) subjected to a process of partial fusion and re-arrangement of particles, yet were not sufficiently altered to efface all evidences of their original stratified structure. This may account for the very highly crystalline condition of the gneiss under description.

Typical localities.

The finest development of this rock may be seen at and near Tiagar-Droog, at Yellanasur (Ellavanasur); at the Yedda Kul rock, south-east of the latter place; at the Cunatur hill, 8 miles north by west of Oolundoorpetti (Wulendurpett of map), and between the Paushur hill and Tirukovilur, on the south side of the Punniar river. North of that river these rocks may be well studied almost anywhere between the line drawn from Mannalurpett to Tandri and the great bay of alluvium which runs up the Gingee river northwards from Vicravandy. In the northern part of this area the beds form the Gungavarum cluster of hills, east and south of Vaturvallum, which may be regarded as merely the southern portion of the Gingee group of hills, into which the beds appear to be continued. These hills present a very unusual appearance when compared with those of the normal varieties of gneissic rock; they appear to be made up of innumerable, large, more or less rounded blocks, which on the ridges often stand out as fine tors. The spaces between the blocks are closely filled by a luxuriant growth of generally thorny climbing and other shrubs; more rarely by trees. Between the weathered blocks and the dense shrub growth the solid rock is but rarely to be seen, and the hills themselves are rendered almost inaccessible. The

Appearance of the hills.

low ground between them is also in great part occupied by dense forest, consisting chiefly of thick underwood, which aids in effectually concealing the face of the country. By far the greater part indeed of the area over which these granitoid rocks are spread is covered with thick scrub-jungle, excepting where clearances have been made for agricultural purposes.

Lithological texture.

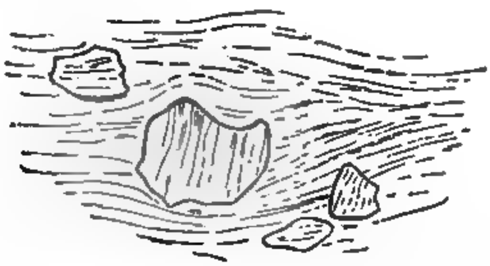
The general appearance of the most typical variety of the granitoid gneiss, as, for example, that occurring at Tiagar-Droog, is that of a rather porphyritic granite, consisting of quartz and whitish and greyish felspar, including imperfect crystals and grains of a reddish or pink felspar. Apparently included masses of an older hornblendic gneiss are very numerous, and occur of all sizes, from that of a walnut upwards to what would appear to be huge boulders of a ton in weight. Included blocks of such very large size are however of very rare occurrence. One of the finest examples was noticed at the village of Kunniyur, 3 miles north-east of Tiagar. Here the included blocks were observed in great numbers, some being rounded and others angular in shape; the largest measured upwards of 4 feet across, and appeared to be deeply imbedded below the surface. Although the matrix has the granitic character strongly developed, none of the included fragments showed any signs of having been exposed to great heat. The included blocks consist of a hard, highly hornblendic schist, which seems generally to resist atmospheric influences far better than does the rock in which they are inclosed. Occasionally, however, they appear to have weathered more rapidly, and to have given rise thereby to cavities much resembling pot holes. Good examples of such included masses may be seen to advantage at Yellavanasur, in the old mud fort, also at Cunatur hill. Five miles east-north-east of Tirukovilur, the granitoid rocks assume, near to the village of Chittanur, quite a conglomeratic appearance; so numerous are the included fragments which in all

Included masses.

Quasi-conglomeratic beds.

cases are of hornblendic schist of black or greenish-black colour. The accompanying sketch (Fig. 2) shows a portion of the bed in question, with

FIG 2.—QUASI-CONGLOMERATIC GNEISS, NEAR CHITTANUR.



several included fragments, the largest of which measures about 1 foot 10 inches in length. The same pseudo-conglomeratic nature of the gneiss beds may also be well observed at Arkadu, where the rocks come down to the bank of the Punniar river in a well-marked ridge; also at Púragil, on the banks of the Teringee Aur, a small river rising near Trinomalli and entering the Punniar opposite to Tirukovilur. Lastly, we have to enumerate a very clear exhibition of included blocks at Seganankottei, about half way between Tirukovilur and Tiagar. Owing to the peculiar constitution of the greater part of the rocks just described, the greater part of the area occupied by them is covered by a very sandy soil, generally of very pale colour, but here and there passing into decided red soil. Cotton soil occurs no where but at the southern extremity of the porphyritic rock districts. The sandy soil consists mainly of silex, with a smaller proportion of decomposing felspar, and not unfrequently a few small lateritic pellets. Owing to the very sandy nature of the soil and the general flatness of country, most of the rain falling on it is absorbed, and in consequence there are but few well-defined water-courses to be met with over this sandy region.

The tendency of the granitoid rock to weather into tors has already been adverted to. They are very common in many parts, and form very conspicuous objects in the landscape from the boldness of their position

Tors.

and from the grotesque forms which have arisen from the irregular weathering of materials possessing unequal powers of resistance. Figures of three such cases are given herewith. Many others might have been selected, but these seemed most striking, either from their magnitude or fine shape. The first of these sketches (Fig. 3) represents two grotesque tors about half a mile south of the Yellavanasur Cotta or fort. They are of some considerable magnitude,

FIG. 3.—TORS OF GRANITOID GNEISS NEAR YELLAVANASUR FORT.

and when seen from a little distance, they bear a not very vague resemblance to two large frogs or toads engaged in some confidential communication.

The sketches (Plate 111) represent a huge tor occurring in the midst of the scrub-jungle between Malayanur and the high road from Yellavanasur to Tirukovilur, at a distance of about 3 miles north-north-east of the

TOR near MALAYANUR

W. Fraser Lith.

former place. Seen from the east or west sides, this splendid tor has a rudely pyramidal shape, but when looked at from the north or south, it rises up like a fine tall tower, and may be seen 3 or 4 miles off standing up boldly from the surrounding jungle. In height it cannot be less than 50 or 55 feet. The lower sketch shows it as seen from the north side.

The fourth sketch (Fig. 4) represents another fine tor perched on the top of a hillock lying between the village of Tirppeir and the Yeddacul

FIG. 4.—TOR OF GRANITOID GNEISS NEAR TIRPPEIR.

rock, before alluded to. The uppermost block is probably about 12 feet high, and appears to stand on a base so small as to suggest its being in an extremely unsafe position. Many of the tors around the hillock evidently owe their origin to the prevalence of a great north and south system of joints, and that figured seems also due to fissures of jointing. As seen from below

Jointing.

(for a profusion of thorny shrubs rendered the hillock inaccessible when visited in 1861) the illuminated face of the tor appeared to coincide with the north-south system of joint planes.

In the Mallayanur tor this was unequivocally the case; indeed, the north and south system of joints is strongly developed in many parts of the granitoid gneiss region.

Epidote.

Of very common occurrence in this series of rocks are little veins and strings, and sometimes incrustations of a bright green mineral, apparently Pistacite, a variety of Epidote. The frequency of occurrence of this mineral appears to be in proportion to the amount of alteration the rocks have been subjected to, and the presence of it is one of the reasons for supposing them to be such increasedly-altered metamorphic rocks, and for not setting them down at once as of plutonic origin. The three or four localities in which it occurred in unusual abundance are mentioned below :—

(a.)—On the south side of the high road, about 3 miles east of Tiagar. *(b.)*—In a ridge of rock crossing the bed of the Guddalum river a mile south-west of Marumvari. It is very abundant there, forming coatings on every plane of jointing, and in some parts seems to enter into the constitution of the gneiss itself, which thus becomes a very handsome stone, owing to the fine contrast of the bright green pistacite and red-felspar crystals. *(c.)*—At Jumbay, 2 miles west of Mannalurpett, pistacite is well seen covering surfaces of joints in the most westerly mass of the granitoid gneiss.

Among the other members of the metamorphic series the pistacite is very rare eastward of the mountains; westward of them, and more especially in the highly altered talcose gneiss occurring so largely to the north of the Shevaroys, it again becomes a rather common mineral, but it no where occurs in any large masses.

Absence of Trap-dykes.

A note-worthy fact in connection with the granitoid gneiss rocks is the extremely small number of Trap-dykes occurring over the whole area occupied by those rocks,

an area several hundred square miles in extent. Those met with also are all rather small in size and of little length. They do not, however, present any peculiarities of structure or of mineral contents.

Details of Metamorphic country.—Over the whole area at present surveyed, the lamination of the metamorphic rocks is distinctly visible, although more decidedly in the magnetic iron beds than in the hornblende rocks and schists. The general direction of this foliated structure is, for the southern and central parts of the area, east-north-east and west-south-west, but in the northern part it trends to the north-east, north-east by north, and even north-north-east. Great and frequent alterations are, however, as might be expected, observable in the neighbourhood of igneous rocks, as along the south bank of the Cauvery, and around and north-west of Togamullay, and in various parts of the country where the strata give evidence of their having undergone immense pressure and consequently extensive disturbance and distortion. Local changes in direction over a small area are very frequently met with, but the original direction is almost immediately re-assumed. Near the village of Poojariputty (13 miles north-west of Trichinopoly) there is a boss of gneiss, which in plan shows a sigmoid contortion in the foliation.* But the beds of which it is composed almost immediately resume their normal strike of east and west at each extremity of the curve. Again 16 miles south-south-east of Caroor, an exactly similar phenomenon is observable in hornblendic gneiss, of the same character as that of Poojariputty, while

Foliation and strike.

* By the term foliation we intend to imply such an arrangement of the constituent minerals entering into the composition of the gneiss as gives to the mass of the rock the more or less streaked appearance which they present. At the same time all our observations have tended to show that, within the area described, the planes of such folia are parallel to those planes obviously resulting from original deposition, and therefore that foliation here coincides, in direction, with stratification. On the exposed and weathered masses of rocks this foliation sometimes shows itself merely by lines of different colours on a tolerably smooth and even surface, as is generally the case in the quartzo-felspathic gneiss. In other cases this foliation has given rise to narrow and slight furrows on the surface, when the more easily decomposed minerals of some of the folia have been weathered out to a certain depth.

east and west of this contortion, alternate beds of gneiss and crystalline limestone stretch away in perfectly straight lines. In both these cases, intrusions of igneous rocks have taken place to a greater or less extent.

Jointing.

Two principal systems of jointing have been observed, viz., one running north-south, (varying 5° or 10° to the east or west,) the other running east-north-east, west-south-west. There are also occasional cases of a system having a north-west, south-east direction. The north and south line of jointing is most constant and distinct, that running east-north-east—west-south-west, being often coincident with the foliation. In the latter case, the constancy of the dip (about 70° southwards) of the planes of jointing was quite sufficient to distinguish it from the foliation. These various systems are very well displayed round the base of the Patchamullays, and the faces of many of the finest precipices of the other mountain groups coincide with some of the chief planes of jointing, of which examples will be found further on.

Joint fissure channels for trap.

In some of the regions of trappean intrusion, the fissures of jointing have been the channels along which the dykes have been formed, as in the set of dykes in the neighbourhood of Volcondahpooram, and again in the trap-traversed region south of Ahtoor, where the north-south system appears to have been the line of least resistance, only three dykes in the former locality being parallel to the east-north-east—west-south-west line.

Form of hills caused by joints.

There can be no doubt that the outlines of the mountains depend greatly upon the systems of joints by which their component rocks are divided. Many examples might be found, but we will quote only three, two of which strongly confirm this supposition—

1st.—The tremendous precipices of Shenguttapandy, on the northern face of the Shairoar hill, the most northerly extremity of the green hill ridges (on the Shevaroys), have their scarps coinciding with a plane of jointing which lies north-west by 5°—6° west, with a dip of 70° north.

2nd.—The fine scarp at edge of the northern plateau basin of the Kolymullays close to Perracurrah, is due to the strong development of two joints which cross each other nearly at right angles. One runs north-north-west, south-south-east; the other north-east by 5°—6° east, south-west by 5°—6° west.

3rd.—The western edge of the western part of the Patchamullays shows a remarkable (see page 16) and very sharply defined scarp, running due north and south, which appears to be entirely due to the north and south joints, which are extensively developed in that part of the country.

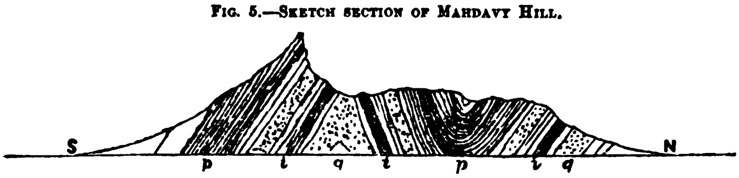
Sedimentary origin of the gneiss.

The sedimentary origin of the gneiss, as far as true bedding offers any proof, is very apparent in many localities. In the southern part of the area, as in the country around Tullamullay hill, Thathengarpaittai, and Toriore, in connection with the magnetic iron beds running from Tullamullay into the Kolymullays, such a structure is very well exemplified. Beds of hornblende rock, quartzose gneiss, (occasionally false-bedded,) and hornblende schist, dipping at various angles, are easily traceable for miles across the level country as streaks of pale and dark rock, as well as on the faces of a few sharp ridges and conical hills. Tullamullay is composed of highly inclined beds, the hardest of which run up to form the precipitous peaks which render the hill so characteristic from all sides of the country. Between Tullamullay and the Kolymullays there is a low mass of ridged hills just north-east of Mahdavy, which on examination shows a structure almost as distinctly marked as are the different beds shown in the accompanying sketch section Fig. 5.

Tullamullay.

Mahdavy hills.

FIG. 5.—SKETCH SECTION OF MAHDAVY HILL.



p, p, Hornblendic beds: i, i, magnetic iron: q, q, Quartzose gneiss.

In plan the beds of rock composing this hill show a very fine example of a great sigmoid curve, and the magnetic iron band* crops out distinctly and continuously all round this curve.

Puggalavaudy.

Again, Puggalavaudy hill (Great Trigonometrical-station) to the south of Toriore, when viewed from the west, shows the different beds dipping south-east by south at an angle of 50°. Standing on any of the thick hornblendic beds half way up this hill, one may trace its descent to the plain, where it runs along eastward for miles, indicated by a dark row of angular debris between similar rows of various width, but of lighter colour.

Of the contortions of the gneissic rocks not immediately connected with any one of the mountain ranges, the most remarkable example is offered by the beds of the Agrarum Kotallum hill, in South Arcot.

That these beds occupy their present position is evidently, in some measure, due to their having been forced up into a broad-backed elevation, the surface of which was then greatly denuded away, leaving the present out-crops exposed to view.

The series of beds here exposed consists chiefly of quartzo-hornblendic gneiss, with the important addition of a large and very conspicuous bed of quartzo-felspathic gneiss (of pink colour generally), which may be traced back to Ommacalatur, 6 miles south-west of the apex of the curve at Kotallum. There is probably a connection with a similar quartzo-felspathic bed occurring still further to the south-west, near Karolanda Kurchi, and it seems probable, if the beds could be perfectly exposed, that the Ommacalatur felspathic gneiss would be found to be an extension of the identical rock which forms a conspicuous bed at the extreme northern end of the Gungavully spur of the Patchamullays.

If such should be the case, the Kotallum beds might fairly be considered as belonging to the Tullamullay-Kolymullay series of the great

* In places round this hill the magnetic iron is converted into a lateritic rock for a slight depth on the out-crop of this bed.

gneissic system, and there seems a very strong probability that such connection really exists in nature, though the extensive spreads of Regur occurring between the two points render it impossible actually to prove this. On the west side of the curve the succession of the strata is much more obscure, and no clear connection with the Kalroyenmullay strata appears to be indicated.

Relation of beds.

As regards the succession or relation to each other of the different series of beds or bands of the metamorphic rocks, very little can be made out at present, except conclusions drawn from local observations. When it is considered that South India is mainly made up of these rocks, and that our own personal observations over a much greater extent of country than that included in sheet 79 tend to show that the different members of the series extend over immense areas, it will be seen that much more extended observations of these rocks will have to be made before any general conclusions can be drawn.

The foliation, or, in other words, the indication of strike of the rock masses over the area now under consideration is, on the whole, from west to east, with a tendency always to curve round more to the north of east until a nearly north by east direction is attained at the northern edge of our area. The relation of the beds may then be studied, to a certain extent, by commencing at the southern limit and taking them according to their succession northwards.

Beds of Cauvery valley.

In the valley of the Cauvery it appears that the rocks of this region are composed of two series, which extend along the valley as three bands in a nearly east-west direction, the most southerly and narrowest being one of hornblendic rocks and schists. Alongside of this is a broad belt of quartzose and quartzo-felspathic gneiss, associated on its northern edge with an extensive and nearly parallel development of granitic rocks. North of this comes the third band, which is very similar in its constituent beds to the first, namely, a hornblendic and schistose series, with intercalated beds of

quartzose gneiss, and this borders the great band of massive syenitoid gneiss of the Kolymullays and Patchamullays.

Neglecting the slight changes in the direction of the dip of the bedding which have been observed in those localities where the intrusion of igneous matter has taken place, there is a very decided connection between the inclination of the beds and these different bands of rock described above. North of the Cauvery and nearly up to the foot of the Kolymullays the rocks have a general dip northwards, while about 6 miles south of the river, where the corresponding band of hornblendic rocks comes in, the dip is reversed, and the beds which lie between that and the northern part of Madura district dip regularly to the south. The region of quartzo-felspathic gneiss lying between these two bands of the hornblendic series shows the same change in dip on its two edges, thus indicating a great anticlinal fold, of which this middle band is the nucleus. The axis of the fold runs with very little variation in an east-north-east direction, and may be traced from Vellyana (8 miles south-south-east of Caroor) by Pereya Sainkul and across Retnagherry hill station, beyond which it is lost in the granitic district to the east. A great fault, with a downthrow to the north, has also apparently been induced along the northern side of this axis, or rather along the band of igneous intrusion, as the hornblendic series of rocks lies much nearer to the axis on the northern side than on the southern.

Great anticlinal fold.

Around Trichinopoly the country does not present so uniform a character in the dip of its rock beds, while immediately south of the Patchamullays and in the South Arcot low country round the Coortalum Trigonometrical Station hill, as well as west of Tullamullay and the Kolymullays, the out-crops of strata traverse the country in great curves, which are distinctly traceable for many miles.

The physical features of the country in which the two divisions of gneiss are described as occurring, differ considerably. The peculiar rounded bosses and hills so common on the banks of the Cauvery, and south of it, *e. g.*, Trichinopoly rock,

Physical features.

Ponmullay, and Erumbeesprum Pagoda Rock, with Retnagherry and Togamullay to the west, are all composed of quartzo-felspathic gneiss, and owe their present form in great part to the hardness and mode of weathering of this variety of gneiss. Great part of the surface of these bosses has been quarried as building material for the religious edifices erected on them, and the workmen have taken advantage of the readiness with which the stone may be split off in concentric surfaces. The country around these hills is also undulating and rounded in its surface, except where igneous rocks occur, when it becomes more rugged in its character.

The region of hornblendic gneiss, on the other hand, with its frequently alternating beds of schist and quartzo-felspathic gneiss, is diversified by numerous ridges and conical hills, surrounded by an almost level country. Very few of these features, however, are seen on the southern edge of our map, as this variety of the metamorphic rocks just comes in at the edge; but Verarlymullay and the Madura mountains further to the south exhibit the characteristic scenery we have described above.

2. MAGNESITE VEINS, &c.

No more striking example of the extreme degree to which metamorphosing agencies have affected the rocks of this area can be adduced than those observable in various places in connection with considerable developments of rocks rich in magnesia; more especially in connection with talcose and chloritic rocks; more rarely, and in a rather less degree, with amphibolitic and other hornblendic rocks. The results of such metamorphic action appear in the formation, locally, of innumerable veins of magnesite, or carbonate of magnesia, traversing what would appear to be the original joint fissures of the rock, which in itself is greatly altered, having become very earthy in texture, and assuming often a very cindery and burnt-up appearance.

The "Chalk Hills."

Such is eminently the case at the so-called "Chalk Hills," 5 miles north-west of Salem, by far the largest and best known of the various areas over which these magnesite veins occur; and a description of this area will give a tolerable idea of the main features observable in all the cases where these phenomena were noticed during the progress of the survey.

Extent of area.

The area over which these alterations have taken place, in the case of the Chalk Hills, is one of very considerable extent, as may be seen on reference to the map; it occupies a space, or rather two spaces of irregular shape, about $3\frac{1}{2}$ miles north of Salem, and covers, roughly speaking, about 10 square miles of ground. The extreme western point on the southern space to which the magnesite veins extend lies a few hundred yards south-south-west of the south angle of the Mancoopum tank (Maungoopay of the map). The veins all appear running along and across a long ridge from one-half to three-quarters of a mile in width, which extends, with slight undulations, in an east-north-east direction, to within half a mile of the western base of the Nagra Mullay, a conspicuous hill lying due north of Salem town at a distance of about 3 miles. The southern edge of the northern and larger of the two magnesite-vein-bearing spaces runs parallel

with that just defined about three-fourths of a mile to the north, not extending so far west, but reaching right up to the very base of the Shevaroys. The northern edge of this area trends to the north-east and north for a distance of about 4½ miles, then suddenly turns sharply, runs for nearly a mile south by east, and again bends to assume a south-east course. The eastern side follows the general curve of the south-west corner of the Shervaroyen, against which it abuts.

This larger area, like the smaller southern one, is rather elevated above the general level of the country, especially along its northern edge, which is formed in part by a succession of low hillocks rising about 100 or 120 feet. Towards the south-east the ground sinks into a broad valley, in which rises the feeder of the great tank just outside of Salem, on the Bangalore road.

Mode of occurrence of veins.

The greatest length of this area is 6½ miles from west to east; the greatest width, 5 miles from north to south. Over the whole of the two areas thus described, magnesite veins occur in innumerable quantities, running in every possible direction; the more important veins, however, as already mentioned, follow certain definite directions, coinciding with the directions of joint fissures observed in the unaltered gneiss rocks of the immediate vicinity.

Direction of principal veins.

The bearings of the principal veins taken by the compass were as follows :—

N. N. E.
N. E.
N. E. by E.
E. N. E.
E.
S. E.

showing a general tendency to a north-east heading in the main veins; but if the minor veins be taken into consideration, hardly a single point of the compass would remain unrepresented.

Aspect of this area.

The aspect of the country traversed by these veins of magnesite is altogether quite peculiar, and so unlike any thing else which has ever previously come under our observation, that we find it difficult to institute a comparison with any other phenomenon seen elsewhere.

The southern or smaller of these altered areas has the form of a low broad ridge, seamed in every possible direction by the veins of magnesite, which being harder than the main mass of the altered rocks, stand out from 3 or even 4 feet down to an inch or two over the general surface, and seam the ridge all over as with a rude net-work. The veins generally underlie at a high angle, or are vertical. The course of the veins is generally straight for several yards; they then turn and follow some other directions, but often divide and twist about in a most puzzling manner. In colour, the veins, where freshly broken or exposed by recent denuding action of heavy rains, are of a pure white, very dazzling and painful to the eyes when the sun is shining brightly. Where the veins have been long exposed to the weather, they have become much blackened, and wherever the rock shows any asperities, or when seen from a distance, present, as might be expected, various shades of grey. Occasionally, however, the grey or brownish stain extends through the magnesite itself, indicating in all probability the admixture of some foreign mineral substance. In width these veins rarely exceed 2 to 3 feet, and are generally very much smaller. Those occurring in the northern area are generally larger than the southern ones, but not so well defined, and more kunkur-like in appearance. Though the magnesite veins are white in colour, these so-called Chalk Hills present but a very faint resemblance to hillocks of true white chalk, which are generally quite smooth, and covered with turf, whereas this magnesite-bearing region is far from being generally white, and is eminently dry, rugged, and barren, hardly any thing but a few stunted shrubs, chiefly of the genus *Dodonœa*, (?) and a thorn-bearing acacia (*Acacia latronum*) growing where the white veins are most abundant.

Associated with the magnesite are minute veins of Baltimorite, or fibrous serpentine, generally of pale green colour, but here and there the largest of these veins (never exceeding 6 inches in thickness) show pieces of a rich blueish-green. The weathered and water-worn rounded fragments to be picked up in the nullahs draining the northern area, not unfrequently show rich tints of yellow, brown, red, and purple, but on the outside merely, proving these colours to be due to weathering only.

Associated minerals; Baltimorite.

Of compact serpentine, only very small fragments were found in one or two nullahs, as pebbles.

Thin coatings of calcedony not unfrequently cover the surface of the magnesite, or penetrate into the mass of it; the calcedony itself is frequently covered with a layer of very minute crystals of quartz. The calcedony appears also in the earthy mass which the magnesite veins traverse, especially in the northern area and at the south-east extremity of the south ridge, and in this reddish or brownish earthy rock, it occurs so frequently as to cause portions to pass into impure jasper, numerous fragments of which, of reddish colour, may be seen strewing the ground, more especially where the magnesite veins are least numerous, *e. g.*, at the east end of the south area, where the matrix rock presents to a very remarkable degree the appearance of having been baked and burnt into a cindery consistence.

Calcedony and jasper.

Here the calcedonic and jaspery coating and net-work of innumerable small threads and veins penetrate the rock in every direction. The magnesite also not unfrequently forms such a net-work in the immediately surrounding rock.

The rarest of the minerals associated with the magnesite, and the only one of any practical value, is chromate of iron, fragments of which occur here and there. An important vein of this valuable ore was discovered many years ago near the centre of the northern area, and was worked by the Company formed

Chromate of iron.

by the late energetic and deserving, though unsuccessful, Mr. Isidore Heath, the projector of the old Porto Novo Iron Company. The mine, which is now abandoned, consisted of several rectangular vertical shafts, from 40 to 50 feet in depth, joined by a gallery at the bottom, which would appear to have followed the direction of the vein.*

When visited in 1861, it was inaccessible from above; it could not therefore be ascertained whether or not the vein had been exhausted, and no opportunity has since occurred of re-visiting the spot. The chromate, judging from one or two hand specimens picked up near the pit mouth, occurs in a true vein or lode, sending off minute strings into the surrounding mass. The specimens in question were not sufficiently large, however, to speak decidedly as to the absence or presence of any gangue or vein-stone.

The mine† is said to have been abandoned for two reasons, 1stly, a failing of the demand for the chromate; 2ndly, the great difficulty of keeping the mine clear of water; but we cannot vouch for the truth of either one or other of the above reasons.

Lastly must we enumerate, among the minerals associated with the magnesite in several parts of the two areas, a mineral which may have been one of the sources whence the magnesite was derived, namely, *talc*. This occurs commonly in the altered rock in strings and scales near Carupoor village, close to where the railway crosses the Salem and Bangalore road. Very pretty silvery-white and greenish scales of talc are numerous also in the somewhat kunkur-like rock occurring a few hundred

* It is impossible now to determine accurately the direction of the underground workings in the galleries, but in all probability they headed north-north-east and south-south-west, indicating the direction of the metallic vein.

† The easiest way to reach the mine from Salem is to follow the path running northwards past the western side of the Nagra Mullay, leaving the south area of the magnesite veins on the left, and crossing the bottom of a tank. The mine is easily found by the tall furnace chimney which still stands close to the shafts, a relic of the old works.

yards east of the Bangalore road, where the south edge of the southern area of magnesian rocks is crossed by a large nullah.*

Associated rocks.

Of rocks not commonly occurring throughout the metamorphic region and evidently connected with the ultra-metamorphic agencies observable in this region, we have to notice two kinds—

1stly.—The earthy-reddish or reddish-brown mass, bearing some resemblance to an impure serpentine traversed by the magnesite veins already alluded to, which occurs very largely towards the eastern end of the south or Mancoopum area, and which predominates all over the northern or Carupoor area. Whether the earthy character of this rock belongs to it throughout, or is only the result of superficial weathering, there was no means of ascertaining in the absence of fresh and deep sections. The section afforded by the railway cutting shows a rather compact and apparently unaltered pale drab quartzo-felspathic rock traversed by small veins of magnesite 'hading' at various and sometimes rather low angles. This spot, however, is so near the extreme western end of the system of magesite veins, that this rock, which is not found elsewhere, and does not appear there as weathering to an earthy texture, cannot be regarded as any thing but a local variety of the gneissic series, which in this part of the country shows chiefly its hornblendic varieties.

2ndly.—We find at the southern and eastern extremities of the great Carupoor area a peculiar black porphyritic rock, highly decomposed, owing its porphyritic character to the presence of numerous not very perfect crystals of a black mineral. This occurs in some quantity between the north-east flank of the Nagra Mullay and the foot of the Shevaroys, but more especially in the stream valley to the south of the site

* Subsequently to my visits to the Chalk Hills, I was informed that compact talc or pot-stone is largely dug in pits at Carupoor village, to be manufactured into bowls and other vessels. I did not happen to come across these pits, though I passed through and completely round the village.—R. B. F.

of Pullyputty village. The surface of the rock is every where so much decomposed that no fresh piece could be discovered from which to judge of its real nature. The matrix of the rock would appear to be hornblendic.

Near to the Nagra Mullay, the appearance of this black rock suggested the idea of its being a dyke-like intrusion of a trappean rock, but east of the Pullyputty nullah, it assumes the appearance of a very coarse hornblendic schist, in which the major axis of the crystals lies in the direction of the prevailing strike of the unaltered hornblendic rocks, situated outside the area of action of the metamorphosing agencies, whatever they may have been. In almost every place where this rather protean black rock shows itself through the thick red soil of the Pullyputty valley, it is traversed by very numerous small veins of magnesite.

Other localities of magnesite.

Such are the more striking features observable over this very singular and interesting tract of country; our conclusions as to the causes of these phenomena will be found further on, after the description of the other magnesite-bearing tracts of country met with during our survey.

Proceeding southward from Salem along the high road to Trichinopoly, we meet, in the neighbourhood of Namkul (Namcul), with a series of great curves, well shown by the low ridges formed by the protruding out-crops or basset edges of the strata, the most remarkable of which are thick beds of hornblendic gneiss abounding in dark red garnets of all sizes.

Mootoonaickenputty.

Following the curve of one of these conspicuous ridges, which lies 3$\frac{3}{4}$ miles north by east of Valiaputty "Travellers' Bungalow" and immediately south of the Moo-oonäickenputty tanks, are a number of small veins of magnesite, chiefly protruding along the line of strike.

The ridge of coarse dark hornblendic and very garnetiferous schist, on the south side of which the magnesite veins are situated, shows a

foliation running west by south, east by north, coinciding with the strike of the ridge which is caused by a protruding out-crop which has a dip of 75° south by east, and corresponds with the north side of a great bay in the general curve of the strata to the east, as may be seen by reference to the map. Though the chief magnesite veins run in the line of foliation, yet other minor ones diverge in various other directions. In size they vary from about one foot in thickness downwards, the average being about 4 or 5 inches across from side to side. Here, as at the "Chalk Hills," the magnesite seems less affected by disintegrating agencies than the associated rocks, and consequently stands out in sharp rugged little ridges. The hornblendic rock, in which these veins appear, has been in several parts, especially at the western end of the ridge, much altered, and has assumed a brownish and jaspery texture, or is covered by a grey or brown impure incrustation. Innumerable fragments of calcedony and coarse jasper are strewn about the surface. These are evidently derived from the breaking up of the smaller veins in which the quantity of accessory siliceous matter is far greater than in the larger magnesite veins.

At the western extremity of the ridge, the set of veins previously running with the strike of the rocks east by north, generally trends first east-north-east and west-south-west and by south to west-north-west, east-south-east, while a corresponding curve is indicated by the gneiss close by running east west with a northerly dip. The hornblendic gneiss ridge, however, has been denuded away at the curve, and a few yards further east, the magnesite veins disappear.

The eastern termination of the magnesite veins is about three quarters of a mile off, where the ground begins to slope rapidly towards the Karavetaur river. The length of the hornblendic gneiss ridge may be about a mile and a quarter. For some little distance south of the magnesite veins, the numerous kunkur concretions scattered over the fields present a peculiar and

Magnesian kunkur.

unusual aspect, being harder and more compact than usual, and having a decided resemblance to the magnesite itself, though quite distinctly a true kunkur. A few hundred yards off across a small water-course this character suddenly ceases, and the common truly-tufaceous character of the kunkur re-appears.

Powtrum.

The next magnesite-bearing tract we have to notice is one of small extent, situated some 10 miles east-south-east from the foregoing, about a mile south by east of the village of Powtrum (Pouthrum of map). The magnesite veins, which are very small here, run along the general line of strike of the highly hornblendic rocks of the neighbourhood, namely, west by south, east by north.

They extend for about a mile or a mile and a quarter along the road to Jembumudda, but are confined to a narrow space, probably not more than 300 yards in width at the utmost, and of this even a great part is hidden by the soil.

The veins occupy the crest of a slightly elevated but well marked ridge commanding a good view of the country. The calcedonic coatings and veinings of the magnesite and impure incrustations between the veins are not quite so frequent in this locality as at Mootoonaickenputty, but more so than is the case at the "Chalk Hills."

Cajareputty.

Proceeding about 6 miles further north-eastward, another small tract of ground, covered with more or less magnesian travertin, is met with about one mile south of Cajareputty, and a little to the east of the road between that village and Moorputty. The magnesite veins which occur on a low broad ridge less than half a mile in length from west to east, are very small, and do not protrude above the general level of the mass, as in the first three cases, but the blackish burnt-up looking tufa and dark coloured incrustation occur abundantly on the surface of the ridge, which consists of an evidently much altered rock, having, on the whole, a strong resemblance to coarse serpentine. A peculiar feature presented by the magnesite veins

at this place is their comparative freedom from calcedonic incrustations, which are very rare here.

In several places on the top of the ridge the travertin-like incrustation presents very strikingly the appearance of having been deposited around small springs, which seem to have discharged their water-like fountains on all sides. Similar phenomena, but still better marked, were observed near Tripunguly, in Trichinopoly district, some 20 miles to the south-east, and of which we shall have to speak presently.

North of the Cajareputty magnesite, are several beds of compact talc or steatite, associated with beds of amphibolite or hornblende rock, and abounding in small acicular crystals of bright green actinolite. This spot lies just within the Trichinopoly district.

Travertin of Tripunguly.

Very similar, indeed almost identical in appearance, with the phenomena at Cajareputty just described, are those presented to view on the high ground half way between the two villages of Tripunguly and Theerampolliam, 10 miles north-west by north from Trichinopoly. Here the surface of the gneiss rock is in various places covered by a pale brown compact travertin, traversed by bands and veins of a white mineral (in all probability of magnesite,) showing by its mode of occurrence that it had been formed from the overflow of small springs, probably (from the similarity of the minerals they yielded,) but so many branches of one important spring rising from unknown depths.

There would appear to have been six orifices whence water flowed, whether they be considered as separate springs, or only as various branches of one main spring. The first of these extinct spring mouths is on a waste piece of high ground to the right of, and on the path leading from, Tripunguly to Theerampolliam, and is about half way between the two villages. About 200 yards north, across a depression which is cultivated, lie the other springs, or rather sites where springs have been closely clustered together, and here it is that the travertin formation of the

springs is most developed. Each spring seems to have formed a very low roundish mound, the sides of which consist of the pale brown travertin, which is in many places permeated by a close net-work of threads, and sometimes by bands, at varying levels, of white magnesite, 3 to 4 inches in diameter. The different and variable thickness of the bands of magnesian sinter may be considered as indicative of periods when the water was more or less highly charged with magnesia in solution. The surface was strewed with fragments of travertin, (many small cavities lined with true botryoidal calcedony of blueish or yellowish colour,) also with masses of coarse jasper.

At the summit of each mound particularly, the rocks have a very cindery and burnt-up look, and are very cellular. Their colour is dark reddish-brown, and they are extremely like some varieties of very vesicular lava, or even pumice, in their external appearance. This vesicular character most likely owes its origin to the permeation of corrosive gases, as carbonic acid gas.

There appear to have been altogether six springs. Where the greatest action had taken place, the eastern side was slightly elevated into a small summit with a crateriform depression about 5 feet in diameter, and a few inches deep, the bottom being rugged and irregular, and the inner sides nearly vertical. The water which no doubt issued through numerous cracks and clefts in the sides, flowed over and formed by precipitation, on cooling, the travertin-like incrustation before alluded to. This incrustation is stalagmitic in character and appearance, and fills up the cracks and joints of the gneiss, and here and there cements numerous fragments into a breccia, not unfrequently containing grains of chlorite and mica. Here and there on the sides of the mounds are indications of the channels for the off-flow of the water.

Not the slightest trace of any organism, whether animal or vegetable, could be found in the magnesite, and in the absence of molluscan remains or other clue, no opinion as to the date of activity of these springs

could be arrived at. The fact that no actual vent was discoverable in the case of any of these springs suggests the possibility of their having ceased to flow, because all passages to the surface were effectually choked by the accumulation of travertin, while the spring was not propelled from below with sufficient force to open itself a fresh channel. The great quantity of calcedony and jasper here, and at Mootoonaikenputty, may perhaps have been due to a high degree of temperature in the water of these springs.

No fossils in magnesite.

About half a mile south-east of the "Travellers' Bungalow" at Volcondapuram, on the Madras-Trichinopoly road, the surface is covered with travertin over several acres of ground. Several veins of not very pure magnesite also occur in the travertin. Chalcedonic incrustations are common, and fragments of jasper very numerous among the scattered debris. The magnesite veins and travertin occupy high ground; to the north and west they disappear, as the ground drops, while on east and south this formation is covered up by cotton-soils.

Volcondapuram.

About 2¾ miles to the south-west, a small vein of beautiful yellowish apple-green serpentine occurs at the foot of the Ellumbaloor hill; it is seen only for a few feet in length in a pit from which laterite road metal has been excavated. Indeed, fragments of this serpentine in the freshly-spread road-metal first attracted the attention of Mr. Blanford before this part of the district had been examined. The serpentine is of very small consistency, and the mass much weathered spherically. Its length follows the same direction as the strike of the adjoining gneissic strata, which is east 15° north. There is probably no actual connection between this serpentine and the magnesian travertin deposit at Volcondupuram.

Serpentine of Ellumbaloor hill.

At a point about 5 miles due north of Volcondapuram and 2 miles north of village of Polliam, another travertin formation occurs, under circumstances nearly the same as those at Tripunguly, differing

only in the absence of white veins of pure magnesite of any size. Fragments of jasper are very numerous, and the peculiarly characteristic net-work of white thread-like veins is very common. As at Tripunguly, Cajareputty, and Volcondapuram, the travertin deposit is situated on high ground.

Travertin of Polliam.

The last of the magnesite localities to be described lies in a straight line 19 miles east-south-east of Salem Bridge, in a small jungly valley, opening out eastward from the Eashurmullay, an extensive but not very high hill about 6 miles south of the "Travellers' Bungalow" at Watapandy (on the Salem and Cuddalore road).

Eashurmullay.

The Eashurmullay is crossed by a bed of compact *steatite,* largely worked as a pot-stone at Tandagoundenpolliam, on the west side of the hill, from which village great quantities of steatite vessels, bowls, &c., are sent away as far as Combaconum (in Tanjore) to be used as culinary utensils, especially by Brahmins.*

The bed of steatite runs about north-north-east at Tandagoundenpolliam, but trends to east by south in crossing the hill, and on reaching the small valley above alluded to, runs along the middle of it. About 3 or 400 yards from the extreme head, it is crossed obliquely by a good sized trap-dyke running south-west to north-east. The contact of the trap and steatite is not seen, owing to accumulations of soil, but the point of intersection is very distinctly marked by the appearance of a quantity of greyish travertin, traversed by unmistakeable veins of

* The pot-stone vessels fetch a high price compared to earthen-ware vessels of the same size, in spite of their rather rude shape. This is owing to their power of resisting the action of fire. Two small sized pot-stone vessels are all that one man can turn in a day, by which he would earn from 4 to 8 annas. Large sized vessels not unfrequently require two or three days' work, which is not unfrequently lost, owing to the presence of flaws caused by crystals of iron pyrites, which almost invariably cause the vessel to crack when they are struck by the workman's cutting tool. The pot-stone is extracted from the bed by means of rude pits 8 or 10 feet deep.

magnesite, resembling on a small scale those at the "Chalk Hills" in every respect. The exact extent of ground occupied by these magnesite veins could not be determined in the thick thorny jungle, but cannot be much less than an acre in area. There can be no doubt that these magnesite veins are due to a further metamorphic action on the bed of steatite, the associated beds of hornblendic gneiss also showing sign of alteration in the shape of numerous little veins and thin coatings of *pistacite ;* and the existence of the heat requisite for such changes being proved by the irruption of the basaltic-trap-dyke.

Probable metamorphosing agency, thermal springs.

These phenomena of re-metamorphism of metamorphic rocks are of such a peculiar character that there can be but small grounds for hesitation in ascribing them to the action of water, (probably of such elevated temperature as to have acted in some cases in the form of steam,) aided by the presence of corrosive gases, especially carbonic acid gas. By the long-continued action of steam and hot water, the disintegration of the rock affected by them would be very thorough and extensive, enabling the corrosive gases to get access to the very inmost recesses of the mass, and the greatest changes of composition and texture of the original hornblendic, chloritic, and talcose rocks would take place, as we see they have done at the so-called "Chalk Hills." Not the least perceptible effect on the physical position of these rocks relatively to the surrounding strata has resulted.

A decrease of temperature reducing the steam to water would give rise to the formation of numerous springs of acidulated warm water, which would dissolve out the magnesia and lime from the well-steamed hornblendic and talcose beds in immense quantities, with smaller proportions of iron and silica. Near the surface these minerals would, on the cooling of the mother liquid, be deposited by precipitation in the open cracks and joint fissures of the rocks, either alone or in combination with each other, as we have seen them to occur at the various localities enumerated and described. In the case of the intersection of a bed of steatite by

a trap-dyke at the Eashurmullay, the metamorphic effect resulted probably from the dry heat emanating from the continuation of the causes which produced the mass of basaltic rock.

The black porphyritic rock described as occurring so largely in a highly weathered condition in the Pullyputty valley may possibly have been an eruptive mass of trap which caused the metamorphic action to be set up.

If this was the case, it would account to some extent for the smaller number of magnesite veins found at that part of the altered tract of ground, as the heat in the immediate neighbourhood would certainly have vaporized any water within a considerable distance till its surface had greatly cooled down, when the magnesite veins now seen traversing it may have been formed by precipitation in fissures caused by contraction in cooling. The temporary continuation of thermal springs would account perfectly for the state of complete disintegration observable on the surface of this black rock.

The formation of such a vast extent of serpentine-like rock, traversed by thousands of magnesite veins, may be yet more easily comprehended, if we suppose that a great part of the area was originally occupied by extensive beds of steatite and other forms of magnesian rocks, the western extension of which remains unaltered to the present day at Carrupoor, as proved by the opening of the pot-stone quarries at that village.

Of all the rocks and minerals at the "Chalk Hills," the constituents could have been, and probably were, derived from the metamorphosed azoic rocks of the immediate locality, with the exception of the chromic acid of the chromate of iron. This probably came from some distant subterranean source.

Age of the magnesite.

Of the geological period of these phenomena little can be said; there is no apparent clue to it, nor have we any means of ascertaining the contemporaneity, or otherwise, of the different series of phenomena; there is, however, a probability of the

spring sites at Cajareputty and Tripunguly not having been exposed to any marine denudation which would most likely have obliterated all traces of them. The period of the activity and cessation of those mineral springs would, therefore, date subsequently to the great elevatory movement which finally raised the cretaceous rocks lying to the east of the magnesites above the level of the sea of that remote time.

The "Chalk Hills" equally would appear to have been subjected to the erosion of atmospheric agencies only, but the thermal waters which gave rise to the phenomena seen there may have been active during the Cretaceous period, as, from their greater elevation of nearly 1,000 feet above the existing sea level, these hills may have still been above the level of the rather shallow sea indicated by the peculiar fauna of those ancient sedimentary rocks, more especially in the Trichinopoly and Arrialoor groups.

Chapter V.—*Crystalline Rocks.*

Of rocks of igneous or quasi-igneous origin, two classes are represented within our area, namely:—

(*a.*) Trap-rocks.

(*b.*) Granites (quartz veins).

Rocks of the first class are extensively developed in numerous dykes which traverse the country pretty generally in various directions, while those of the second class are confined more especially to the southern part of the area.

Trappean rocks.

(*a.*) *Trap-rocks.*—By far the greater number of the dykes met with consists of coarse-grained black or blueish (or greenish) black, and very hard, tough basaltic trap, but without olivine, except in two cases to be mentioned presently.

Associated locally with this rock, as thin strings running into the adjacent gneiss, and often even permeating the coarser rock itself, is a fine-grained blueish-black trap, which is generally more split up by jointing than the basaltic, or coarser, variety.

Columnar structure.

Columnar structure has not been observed well marked, but jointing is often developed to a great extent, frequently producing polygonal blocks, which sometimes pass into the cannon-ball form so frequently seen in weathered dykes. The same systems of jointing as are seen in the gneissic rocks are, with slight variations, seen in the trap.

Greenstone or *Diorite* was observed in several cases in which the rock was markedly porphyritic.

One case was observed at the edge of a spread of laterite about a mile south-east by south of Thooanagoody "Travellers' Bungalow," on the road between Trichinopoly and Tanjore. The other about 6 miles south-south-west of Trichinopoly, associated with some large veins of granite and quartz. In the country drained by the Vellaur and its tributary, the Pereyaur, there are two principal separate series, or groups of trap dykes.

Principal series of dykes.

1st.—Those aggregated in the valley of the Vellaur Proper, or the Volcondapuram region, and—

2nd.—Those in or about the valley of the Pereyaur, more properly belonging to a region of trappean intrusion lying among the Pythoor hills, south of Ahtoor, in the Salem district.

Dykes of Vellaur valley.

In the first series the general direction is north by west—south by east, but in one or two cases a north-east by east direction has been followed. Here there are at least seven well-marked and long dykes of basaltic trap, all of which are exposed for a length of 4 or 5 miles, but the further extension of which it is impossible to make out with certainty, on account of their being so much covered up in different places by the thick cotton soil of that neighbourhood. These may be specified as follows :—

1st.—The Thavyur dyke, which crosses the Madras road about 2 miles north-east of Volcondapuram in a north-west—south-east direction.

2nd.—The Pulioor dyke, about half a mile east of the former, runs for about 4 miles north by west—south by east.

3rd.—Further east, about 8 miles from Pulioor, are two fine dykes near the village of Nunnay.

4th.—Where the Madras road crosses the Vellaur by a ford at Tooloodoor Tuckuri, there is a regular assemblage of small basaltic trap-dykes.

5th.—A large dyke, about 5 miles long, crosses the Vellaur at Agrarum (Korawadi of map), about 4 miles west of Tooloodoor. A reference to the map will, however, show the true position and extent of these better than any lengthened details, and it is only necessary to treat separately of those which are remarkable for some peculiarity of mineral composition, mode of occurrence, or great size.

Westward of the dykes just described, are several groups of others worthy of notice because of their size or the complicated relations of the several members of the groups.

Foremost among these we must enumerate the great Pythoormullay group, the second of the Vellaur valley series.

Pythoormullay group.

This consists of two main and several smaller branches diverging from each other to the north-west and north-east (roughly speaking) from a spot on the southern slopes of the Pythoor-mullay group. In size these two dykes are about equal, but the eastern branch may preferably be regarded as the main branch of all, as being of more considerable length, and having a course more generally persistent in one direction. In mineral character they are identical, and were probably formed during one and the same volcanic paroxysm.

The main branch was traced through the dense jungle between the Patchamullays and Kolymullays, from the Mungumaputty hill north-eastward, with slight variations in its course to within a mile of the Sharvoye hill Trigonometrical-station, a distance of 17 miles.

The second branch extends from the point of divergence in a north-north-west direction to the banks of the Vellaur river, and is lost sight of in the alluvial bank after a course of 14 miles from the point of divergence. Both branches form ridges of considerable size in various parts of their course, rising from 500 to 1,000 feet and upward, the dark black line of trap rocks showing most conspicuously on the slopes of many of the higher hills they cross, as, for example, the Pythoor hills and the Mulliakurry Trigonometrical-station hill. The branches offer no remarkable features beyond their number and rather strange local distribution. Though of great magnitude, the dykes of this group have no where caused any apparent disturbance of the rocks into which they were injected, hence it seems not unreasonable to conclude that they occupy lines of joint fissures of greater antiquity, because already in existence when the volcanic processes were set up by which the basaltic rock reached the surface. In favor of this view of the origin of these dykes is the fact that, at the points of junction of the various branches and cross-dykes, there is no intersection indicative of the dykes belonging

to two epochs, but, on the contrary, there is a simple junction of homogeneous rocks, or, if there be any difference in the texture of the trap, it consists only in the rock composing the smaller branches and dykes being rather more compact and fine-grained than in the larger ones.

Vailoocoorchy dyke.

Westward of this system of dykes, we observed a remarkable dyke stretching in an almost perfectly straight line from the ridge of the Neinahmullay (8 miles north-north-east of Namcul-droog) in a north-east by north direction for 12 miles. It is not unlikely that it may be continuous with a large dyke running from the east flank of the Anandymullay, near Jyelputty, to within a mile of the tenth mile-stone east of Salem, on the Cuddalore road. The break of 4 miles between the two dykes, as shown on the map, would probably be filled up, could the surface soil and jungle be removed from the flanks of the Anandymullay.

Dislocation of magnetic iron beds.

This dyke is remarkable because it appears to be connected with a great dislocation of the gneissic strata which it crosses. This dislocation, which has already been alluded to in the Chapter on the magnetic iron beds (page 64), would appear to consist of the shifting of the beds forming the great magnetite ridge of Vailoocoorchy by a fault, the downthrow being to the northward.

The fault appears along the outline of a curve in the bedding, by which the amount of downthrow appears to be enormously exaggerated.

The evidence in favor of this downthrow consists in the absence of iron beds on the north side of Vailoocoorchy village corresponding with those on the ridge north-west of that place, and in the diminution of the angle of the beds on the east side of the fault to 72° south from a dip of 85° south, at the east end of the ridge north-west of Vailoocoorchy. Whether or not the trap-dyke was formed at the same time as this line of fracture, or the trappean rock subsequently injected, there is no evidence to decide.

The country between the two corresponding beds of magnetic iron, in other words, along the line of shift, is covered by thick soil, and no signs of any fault-breccia were met with.

Huroor and Adamancotta series.

Northward of the Shevaroys and the Tainandamullay ranges, the southern part of the Baramahal plateau terrace is traversed by a rather remarkable series of large trap-dykes having a north-westerly course. Exactly speaking, they run from south-east by east to north-west by west.

The series is composed of five dykes, which, though in many places they may be tracked for miles, are yet here and there hidden for considerable distances either by accumulations of soil, or else by jungle. They generally project well above the surface of the country, and are very conspicuous, sometimes forming ridges of no small magnitude.

Courmullay dyke.

The southernmost of the dykes crosses the northern end of the Munjawaddy pass from the western flanks of the Tainandamullay; is then lost for a distance of 4½ miles, but re-appears and crosses the Courmullay, and also the broad valley through which the railway reaches Mullapooram station.

The Durmahpoor mountains are crossed by the dyke in great force, but it is again lost for several miles under a thick spread of cotton soil north-east of Adamancotta. It re-appears immediately west of the Salem and Bangalore road, and after a further course of 4 miles, extends beyond the limits of the country under survey. Including the breaks, the length of this great dyke is about 28 miles.

Moonimullay dyke.

About 5 miles to the north is another large dyke, following a very nearly parallel course for 23 miles, without any important breaks. Like the former one it crosses the Durmahpoor range, just south of the Mookanoor Trigonometrical-station hill.

The third of this series is a smaller dyke running nearly parallel with the foregoing, with several discontinuities however.

Huroor dykes.

The two northern members of this series are very fine trap-dykes, descending from the northern end of the Tainandamullay, crossing the Carapaudy ridge, and descending thence in two very conspicuous spurs, they run north and south of the Huroor hill, and may be traced with a few breaks from Huroor, till they cross the limits of the map after courses of 27 or 28 miles, remarkable for their close parallelism. How great the westward extension of these dykes may be, remains yet to be ascertained, and their extreme eastern termination may, in the case of the three more southerly members of the series, be found hidden in the dense forests of the Tainandamullay a mile or two east of the spots they were traced to at the time of the survey.

Absence of dykes south of Cauvery.

It will be seen that the distribution of the dykes is very irregular; none of any size were met with south of the granite region on the north bank of the Cauvery, while all over the country occupied by the "granitoid gneiss," the trap-dykes are few in number and small in size.

Dykes of Cunum hill.

Eastward of the granitoid gneiss region they again appear of larger size, as, for example, the two very remarkable dykes running from Semangalam, 12 miles north-west of Pondicherry, through the Cunum and Perumbakkam hill stations to the Trichinopoly and Madras road. Of all the dykes met with, none present so remarkable a case of parallelism as these two; when seen from the village of Cunum, they present a very remarkable appearance, not easy to be described, but suggestive of two rather crowded rows of ruined "martello towers" of black colour, the ridges having been eroded into an avenue of rather tower-like black bosses.

Several of these bosses cannot be much under 100 feet in height above the very flat country at foot of them.

Mineral character of dykes.

The general mineral character of by far the greater number of the trap-dykes scattered so profusely in various parts of our area, is identical; they consist generally

of a rather coarse-grained, but exceedingly hard and tough, black basalt-like mass, hardly ever containing recognizable crystals of any foreign substance.

In a few cases the fresh fracture showed a greyish lustre, due apparently to numerous small crystals of a felspathic mineral.

Porphyritic trap of Kotallum.

In the case of a dyke occurring close to the village of Agaram Kotallum, north of the Kotallum hill station in South Arcot, the black rock contains numerous crystals of a glassy variety of felspar, resembling Labradorite in texture and lustre, but without any iridescence. These are probably a variety of Sanidin. The crystals obtain a size of as much as 2 to 3 inches in length, by from 1 to 2 in width, but are generally much smaller. The matrix is very black and exceedingly hard, so much so that even a heavy hammer failed to make any impression on the spherically-weathered masses. This dyke is but of small extent, and none of the other trappean intrusions in the neighbourhood exhibit these crystals and the resultant porphyritic character. The course of this dyke is from south-west by west to north-east by east, and it gives off a branch of equal size with itself with a north-easterly course.

One of the most striking features in the rocks being the almost total absence of olivine and titaniferous magnetic iron, which minerals are so characteristic of the generally more common and typical variety of basalt, there can be little doubt that most of these dykes may be considered as of Anamesite.

Olivine was met with unmistakeably in only two of the many score of dykes examined, namely, at the Pulioor trap-dyke before named, and in a large dyke south-east of Vettratty, in the Tummumputty valley.

Geological age of the dykes.

Of the age of the trap-dykes, we know only that they are pre-cretaceous. The evidence of this is found in the case of the dykes at Puravoy, above alluded to, and

in the greenstone dykes of Ootatoor,* all of which disappear under the cretaceous rocks without in the least affecting them. Had the dykes been formed by intrusion of the trappean rocks after deposition of the beds of the Cretaceous system, the latter must inevitably have shown signs of alteration at the point of junction, even if they had not been penetrated themselves by the eruptive masses.

Majority pre-cretaceous.

From the great similarity of mineral character, it does not seem rash to argue the probability of the dykes, *generally*, being of pre-cretaceous age.

The economic capabilities of the trap rocks will be touched upon in the Chapter specially devoted to Economic Geology.

Size of dykes.

The lengths of several of these important examples of intrusive rocks have already been given, their thickness is very variable, but they are very frequently so situated, that either by soil or jungle great part of their thickness is concealed, while in other cases the fallen blocks lie so thick, as to render it impossible to either measure or estimate exactly the real width. This is especially the case where the dykes form elevated ridges. The greatest width actually measured (by pacing) at the northern end of the Pulioor dyke was about 200 yards, but the average width of the dyke is only about 40 yards.

A dyke exceeding 50 feet in width would be reckoned a good sized one, and one more than 100 feet across, as of first class size. Many examples of small branches a yard or two, but often also much less, in width were noticed, whose course was quite sharply defined like the foundation of a wall, and might be traced for some little distance.

In some few cases the branches could be traced till they tapered away to 1 or 2 inches in width and then died out altogether.

(*b.*) *Granites and Quartz veins.*—The greatest development of granite occurs in the Trichinopoly district, along the north bank of the

* Memoirs of the Geological Survey of India, Vol. IV, part 1, page 37.

Cauvery, in a band stretching from the neighbourhood of Erungaloor, about 10 miles north-north-east of Trichinopoly, as far west as Caroor, and in all probability beyond that point. This band is from 4 to 6 miles wide, measuring from the edge of the alluvium northwards, and is made up of reefs of granite which run generally in a north-east by north direction. The rock appears to have been intruded between the planes of bedding of the gneiss. It is, as a rule, largely crystallized with but little mica, and contains very large felspar (Orthoclase) crystals of a rich salmon colour.

Granite of Cauvery valley.

A very common form of granite throughout the Trichinopoly district is a binary variety, consisting of felspar and quartz, in which the felspar is usually of a white or yellowish-white colour; though typical granite (quartz, felspar, and mica) is of frequent occurrence. About 7 or 8 miles south-south-east of Trichinopoly there is a very fine vein of this last in the bed of a stream near Poodoor, in which the crystals of felspar are very large, some of 4 or 5 inches in diameter, and in which the mica occurs in long flat prisms of 2½ inches in length. This vein, like another of identical character at Naivailie, a few yards south of the crystalline limestone, shows two structures; the sides of the vein are irregularly crystallized, while internally it assumes the structure of graphic granite. West of the road from Encongoor to Trichapoor (Koolitullay Taluq) is a large vein of binary granite in which quartz greatly predominates, but the crystals of felspar, when they occur, are of immense size, sometimes as large as 2 by 2½ feet and more. Felspar crystals of yet larger size occur in a granite vein at Colingaputty (in Namcul Talook, Salem district) associated with plates of talc. In a granite vein of largely crystallized structure between the Magnesian travertine deposits (page 99) at Tripunguly and Trevellary Pagoda, we found a very beautiful variety of felspar of a rich leek green colour. Some blocks of granite from neighbouring veins, in which the felspar is of a deep salmon red

Binary granite.

colour, have been quarried and used as steps, etc., in the Pagoda at Trevellary, and where from use and friction they have been polished, they present a very rich and handsome appearance.

Of the granite and quartz veins met with in other parts of the area noticed in this report, only a few require any separate mention, on account of their having distinguishing features.

Crystal cavities in quartz,

In several instances the quartz was found to be full of cavities, which had evidently contained rhombic crystals of some accessory mineral (possibly carbonate of iron,—spathic iron); occasionally a rusty-looking mass of decomposed matter is found remaining in the corners of the cavities, which suggests the idea of its being the remnant of decay of the crystals which originally filled the cavities. In no case was any distinctly recognizable substance found occupying the cavities.

near Salem.

These cavities were observed in quartz and granite veins; we observed them in a quartz vein of no great size, running close to the Bangalore road at the foot of the first hill out of Salem. They are also to be met with in a large quartz vein on the north face of the Meckalupoor hills,* about 3 miles south-west of Ahtoor. Here the cavities are exceedingly numerous, but of rather small size; the diameter of the crystals having been rarely more than half an inch. They occur, too, in a large ridge of quartz which crosses the high road between Huroor and Morapoor. In this case many of the cavities contain a little of the rusty-looking clayey matter adverted to before. This quartz vein, being associated with talcose-schists, was carefully searched for gold, but not the least indication of the precious metal rewarded the search.

Nor was the searching for gold more successful in a small quartz vein (containing similar rhombic cavities) on the south-east flanks of the Godumullay, where it is seen *in situ* in the indurated talc-schists.

* Called Meckalupoor on the Atlas sheets, but should properly be Malakupoor, or Upper Kupoor.

In a granite vein at the village of Vapanuttom (3 miles from Namkul), many of the quartz masses show very perfect cavities that had apparently been occupied by rather tabular-shaped crystals of felspar. Some of the cavities are fully 2 inches in length. Another small vein, remarkable for containing occasionally nearly perfect (pseudomorphic) prisms with terminal pyramids of bright silvery-grey mica, occurs on the south side of the low hills lying north-west of Vapanuttom, which forms the apex of a great curve in some of the hornblendic and garnetiferous beds belonging to the great Kolymullay-Tullamullay series.

Schorl rock.

Prisms of black tourmaline or schorl were met with in great numbers in a quartz vein having a north and south course, and lying immediately south of the village of Aulthromputty, in the great Oopillipooram valley.

Obscure and badly shaped crystals of the same mineral occur in small veins exposed by a nullah running into the Guddalam river, close to the village of Vundaraddi, in South Arcot.

The large granite vein of Colingaputty, already alluded to as containing enormously large crystals of felspar, contains also large plates of coarse blackish-green talc.

Besides the accessory minerals already named, none else were observed in the granite veins but garnets and grains of magnetic iron.

Graphic granite.

Graphic granite occurs in the central part of two large granite veins, the first of which is situated on the south side of the crystalline limestone at Naivaillie, and the second, in the great vein extending from the Tipramahdevy hill to the travellers' bungalow at Valiaputty. In both cases the outer part of the veins consists of common coarse quartzo-felspathic granite, without any trace of the graphic arrangement.

A very large but only slightly exposed granite vein runs from a little south-west of Darmahpoor as a ridge across country in a direction to near the top of the Toopoor Pass, a point lying beyond the confines of

our map. Judging from the great quantity of debris, the vein would appear to be one of great magnitude, but it is greatly covered up by superficial deposits. The greater part of this debris being quartz, it might be supposed to belong simply to a quartz vein; but a little search soon shows the existence of felspar crystals with the quartz, combined to form a binary granite. This vein varies considerably in its width, and is occasionally lost sight of for a few yards, but soon re-appears.

White Elephant rock.

One of the most remarkable masses of quartz to be seen in this part of India is the "white elephant rock" on the east flank of the Gundoor, or southern-most, spur of the Shevaroys. This huge mass of apparently pure white quartz rises precipitously to a height of probably 100 or 120 feet from an irregular base, the diameter of which may be estimated approximately at about 200 feet. The whole mass is much cut up by large vertical joints. When seen from between the trees, it is, from several points of view, not at all unlike a great white cathedral towering over the forest around it. The rock is by no means easy of ascent, on account of the great steepness of the sides, which, in most places, are vertical and everywhere very smooth and slippery.* This rock is a most conspicuous object, from many points of the Ahtoor valley being visible on clear mornings for upwards of 35 miles. A corresponding but rather smaller mass of white quartz stands on the west side of the Gundoor spur, overlooking the magnesite veins of the so-called 'Chalk Hills', apparently at a rather

* Great care is requisite not to rouse the swarms of wild bees which inhabit the summit, for, to be attacked by them where a hasty retreat is impossible, would be dangerous in the extreme. I succeeded in reaching the top (in company with Dr. H. Crocker, of the Madras Medical Service, who kindly became my guide to the rocks,) but only by having recourse to some very rude bamboo ladders left by the Mullayali honey-gatherers in the rift (due to a natural joint) on the south face of the great rock.—R. B. F.

greater elevation above the Salem plains. Most probably a connection exists between this and the great rock above described.

Besides these distinct and probably latest intrusions* of granite among the metamorphic rocks, there are distributed all over the valley of the Cauvery, from Caroor to Trichinopoly, and beautifully displayed on the numerous bosses and hummocks of quartzo-felspathic gniess of that region, thin strings and veins of granite, varying from a few inches to a foot in thickness, and of these there are two systems, one of which very often crosses the other. In the newer, the walls of the veins are distinctly marked, while in the older the lines of separation are seen with difficulty, these having been obliterated by re-metamorphism. Enclosed fragments of gneiss torn off by the granite during its intrusion are by no means unfrequent.

* It would appear as if there had been at least three periods of intrusion of granite in the rocks which now constitute the gneissic series, two of which are apparently much older than the third.

We have first the two systems of small veins of which those with the scarcely distinguishable walls are traversed by the more distinct; but these are all so compacted with the traversed rock, so old looking, and so diverted from what would appear to have been their original direction, by the squeezing and folding which the gneiss has undergone, that one can hardly help considering them to have been part of the great system of rocks traversed by the apparently later outburst of the Cauvery belt. Though the granite of Togamullay and the Cauvery bank traverses rocks which are permeated by the system of smaller veins, still I remember no case of distinct separation between what I take to be the older and newer granite. This, however, could hardly be expected, for the two granites at their junctions would be so fused together, that any decided separation could hardly be made out. Such differences in the granite would then imply at least two great periods of metamorphism: one when the first series of granite veins was formed; the other during the intrusion of the granite of the Cauvery belt, etc. My subsequent observations in Nellore and Cuddapah show that there have indeed been two such periods, but whether these have any connection with the igneous features of Trichinopoly district, etc., is yet to be made out. In the Nellore and Cuddapah districts is a series of clay slates and quartzites, themselves metamorphosed, conglemeratic, and ripple marked, which rests unconformably on the older and much more altered gneissic rock of South India.—W. K.

Enclosed fragments in granite veins.

A very interesting example of this last feature may be seen in one of the most prominent granite ridges near Chinna Vungarum, about 3 miles north by west of Samiaveram "Travellers' Bungalow," where a mass of well foliated gneiss of irregular shape, but several feet in length, is visible, imbedded in the mass of the pink granite. Again, in the large and extended outburst of granite which has taken place north-east of Togamullay, (a gneiss boss 20 miles west-south-west of Trichinopoly,) immense masses of hornblendic schist, 30 or 40 square yards in extent, appear to have been, as it were, floated about, while their ragged edges are lengthened out until felspar, quartz, mica, and hornblende have been twisted into a thin rope of different coloured strands. In all cases the laminæ of felspar appear to have been lengthened out and twisted to a greater extent than those of the other minerals.

CHAPTER VI.—*Superficial Deposits and Soils.*

Among superficial deposits there are three more especially deserving of notice, because, though they often occupy merely the position of surface soils, they often also attain to such extent and thickness as really to demand the rank of geological formations; and further, they are almost peculiar to India. These are *Laterite, Cotton Soil,* and *Kunkur.*

Laterite already treated of.

In the country we are describing, laterite occurs more particularly associated with the post-cretaceous rocks; and on this account we have described this rock in the Chapter devoted to them. The peculiar phenomena observed in connection with cotton soil will be touched upon when treating of soils considered with reference to agriculture.

Kunkur.

The greyish-white calcareous deposit generally known under the name of kunkur occurs commonly over the whole country, generally as little grains or concretions, or small agglomerations of such in the soil; very often also as a travertin-like deposit on the surface of the rocks in river beds, where it occasionally forms the matrix of coarse conglomerates and breccias. Less frequently it is to be seen as the result of decomposition *in situ.*

Two forms of

This rock in some respects resembles laterite in its mode of occurrence. It exists in like manner under two different forms, which are the result of deposition from water in the one case, and of decomposition of the rock *in situ* in the other.

concretionary kunkur.

The first form is kunkur proper, and is more commonly observable as a semi-concretionary deposit of a white, grey, or light brown colour on the surfaces and in the joints of rocks, particularly on the banks or in the beds of streams. The concretions are essentially composed of carbonate of lime, in a matrix of the same mineral; but small grains of quartz and gneiss often replace these. Another form of occurrence is that of single pisolitic grains,

or small accumulations of these, in the different soils, and cotton soil is so largely impregnated with it in some localities, that it almost loses its distinctive character as 'Regur.' Such a change is very well seen in the Toriore talûq, where the village of Puttoor is situated on black, porous cotton soil, which becomes almost a marly soil half a mile to the north, from the enormous quantity of kunkur particles contained in it. The ordinary 'chunam' of the natives is made from the small nodular concretions. The conglomeratic form of kunkur is not of very frequent occurrence to any large extent, but it may be well seen in the banks of the Thalooghay-aur (river), a few miles south of the low ridge which forms the junction between the Kolymullays and Patchamullays. Here for about 2 miles the banks consist of thick masses of conglomerate, in which fragments of almost every variety of rock of the neighbourhood may be detected. The conglomerate not unfrequently forms cliffs running along the waterside at a very equal level, and presenting the appearance of quays of artificial construction. Similar kunkur quays may be seen on the banks of the Vellaur, a few miles below where it issues from the Tainandamullay range and also on the banks of the Pereya-aur to the west of Tummumputty, and again between Luddawaddy and the junction with the Ellayaur. A breccia formed by kunkur is of much rarer occurrence; an example of it may be seen in the Conari river, near Runjenguddy Droog (Trichinopoly district); and south of Caroor, small portions of the kunkur quays sometimes include nothing but angular fragments, and should in that case be called breccias. Though not occurring in our area, we may instance a very fine example of a true conglomerate which occurs at Bhowani, near the junction of the river of that name with the Cauvery in the Coimbatore district, where there is a deposit of kunkur in the bend of the generally dry bed of the river enclosing pebbles and huge rounded blocks of quartz and gneiss. In many places this conglomerate is 4 or 5 or more feet in thickness. Much more rare than the conglomerate cliffs are cliffs of concretionary limestone formed by infiltration of cal-

careous matter held in solution into sandy soil. Such may be seen in several places on the banks of the upper reaches of the Vellaur and some of its tributaries. Where the infiltration process has been active, a rude branching, and faintly coral-like mass of kunkur concretions becomes solid a yard or two higher up in the section, while in a downward direction the branches become disconnected, and further down still the kunkur occurs only in pellets imbedded in the red sand. The horizontal extension of such aggregations of kunkur are generally limited to a few score yards, where the infiltration has been but trifling; only a few rudely cylindrical concretions may be seen in a vertical position.

Kunkur from decomposition *in situ*.

The form of kunkur resulting from the decomposition of gneiss *in situ* has only been observed to any extent in sections exposed by the digging of wells, and these are mostly in the neighbourhood of alluvial deposits, such as the cultivated flats below tank bunds, and spreads of cotton soil, the difficulty in these cases being to find a fresh section. At Runganadapooram, 3½ miles north of Toriore, the following section was found in a recently dug tank: at the surface, cotton soil containing grains of kunkur; this, after a foot or so in depth, gradually changes into a white semi-compact kunkury marl, having small grains of gneiss and quartz in it. There is about 2 feet of this, when another gradual change into true gneiss *in situ* appears. In this space of change from kunkury marl to gneiss, there are remains of folia with fragments of undecomposed gneiss in position, having their laminæ parallel to the true direction of foliation. A like change is also often observable on the banks of streams, where the gneiss is decomposed into a white calcareous rock of marly appearance, for some inches from the surface, which still retains foliation marks and undecomposed laminæ of quartz and mica, and occasionally sporadic garnets.*

* Since the above was written, I have seen numerous instances of kunkur resulting from decomposition of gneiss *in situ* especially among hornblendic schists. Such instances are very frequent in the schistose gneiss of the south-eastern portion of the Nellore district.—W. K.

The greatest development of both of the above forms of kunkur has been observed, as might be expected, in those parts of our area in which hornblendic gneiss or basaltic trap prevail, there being about seven per cent. of lime in hornblendic rock, while as much as nine per cent. of the same mineral occurs in some basalts. In the neighbourhood of Vellyana, about 8 miles south of Caroor, there has been a great deposition of this rock, hornblendic gneiss occurring there to some extent, accompanied by basaltic trap; it is also pretty frequent in the neighbourhood of the crystalline limestone further south, while over the whole of the country north of the Cauvery, instances of the several forms of the deposit may be frequently seen. Kunkur is generally of a dirty white colour where pure, but the presence of iron renders it brown or reddish in hue. It occasionally assumes a pisolitic or botryoidal form, and is then of reddish-brown or dark brown colour, and very compact.

Age of kunkur.

As regards the age of this deposit, as far as we have seen, it would appear to be essentially recent, and there can be little doubt but that the formation of all the varieties of kunkur mentioned above is now in progress in every part of the country where calciferous rocks are being acted on by atmospheric agencies. It was seen in one case overlying the cotton soil, on the west bank of the Conari river, which runs to the north past Thavyur, in the neighbourhood of Volcondahpuram, where a gritty deposit of gneiss particles in a matrix of kunkur lies on the gneiss, and is spread over the adjacent cotton soil to some small extent.

Kunkur pebbles formed by the wearing down of angular fragments or of large concretions may be found in the upper courses of several of the larger rivers and streams in considerable quantity.

Soils.—Under this head we include, irrespectively of their origin, those formations generally but slightly coherent which form the upper surface of the country, and therefore come under the hands of the agriculturists.

Four classes of soils.

The various soils which occur over the large area treated of in this report may be conveniently referred to the following four classes:—

I. Red soils.
II. Alluvial soils.
III. Black soils.
IV. Mixed soils.

These will be treated of in succession according to their relative importance as they are arranged above.

Red soil: Lâl.

First in importance, because covering by far the greatest area, is the 'Red Soil' or 'Lâl,' the ***Cevippu man*** of the Tamulians, which is for the most part a sandy soil, and is perhaps most typically seen on and in the neighbourhood of the Cuddalore sandstones, where it is, on the whole, either the result of the weathering of the sands *in situ*, or a loose deposit of materials derived from the adjacent rocks. There it is a highly ferruginous soil, but occasionally clayey, and then of pale yellow and greyish-brown colours, and on the whole not very productive. Generally it is thinly spread over the surface as in the Woodiarpolliam Talûq, and in the neighbourhood of Vellum; but instances have been observed where it attains a thickness of 4 feet or more. It is, as a rule, very fine grained, but becomes coarser towards the bottom, where a thin layer of rounded quartz pebbles is of frequent occurrence.

The surface is often hardened or caked, the furrows, even in freshly ploughed fields, becoming compacted after some days' exposure.

Red soil, especially the sandy variety, covers by far the greater area in the metamorphic regions. Around the foot of each of the mountain ranges, the red soil occurs in a belt, a mile or two in width, forming a deposit of fine red sand, having a caked surface, like that observed on the soil covering the grits.

It is generally 4 or 5 feet deep, but a much greater thickness is often observable in the peculiarly deep and narrow gullies which have

been worn in the deposit by the streams. In one very good example, north of Toriore, a perpendicular-sided gully below Goondoor Peak, the bottom of the soil is not seen even at a depth of 15 feet.

At various depths there are layers of rolled and sub-angular fragments of gneiss and quartz, the size and quantity of the boulders decreasing in proportion to the distance from the base of the mountain. In the bed of a stream which flows west from a narrow neck on the Patchamullay plateau, past Woodianputty, to the Permalpolliam tank, some very characteristic deposits of boulders and gravel are to be seen. A vegetation similar to that of the grits, such as Tamarind, Mango trees, and Euphorbias, with other thorny plants, characterises this belt; at the time of our survey, the castor-oil appeared to be the plant principally cultivated on it.

The *Lâl* is in many cases nothing more than the result of the decomposition of the underlying or closely adjoining rocks of the metamorphic series, which are all more or less ferruginous, and have a more irregular texture than the grits.

Fertility of coarse arenaceous soils.

The red and sandy soils are very largely cultivated for, and appear to be admirably adapted to the growth of, dry grain crops; the survey of the country south-west of Trichinopoly was being conducted in the months of September and October, and at that time most luxuriant crops of *cholum, cumboo,* and *ragee* were ripening on all sides. Many of the cholum crops were 8 or 10 feet in height, while the ears of grain were correspondingly large. In the month of July fine crops of the Gingelly oil plant (*Sesamum Indicum*) were noticed growing on the red sandy soil of the Cuddalore sandstone plateau. The same plant appears to thrive also on an identical soil in the neighbourhood of Trivellore, 25—30 miles westward of Madras. This part of the country is also much better wooded than any other part of the country which is not actually covered by forests, excepting only the eastern edge of the delta. A view from any of the elevated ridges

shows this most strikingly. Spreading away to the east and west and up to the Cauvery, which is indicated by a dark green belt of palm-trees lining its banks, is an irregular waving country, covered with cultivated tracts, and lines and topes of fine trees, among which are scattered numerous villages, while massive granitic bosses and large tanks remove the sameness of what would otherwise look like a great wooded plain.

The same character of country, as far as regards the surface soil, distinguishes the greater part of the district in which the granite is developed on the north bank of the Cauvery; but hornblende rock and schist come in here, and are in this case covered by cotton soil and its varieties.

With regard to the connection of the red soil with the underlying rocks, we may observe that where granite and quartz abound, a coarse dry soil of reddish or brown colour prevails, as is the case over the greater part of the Trichinopoly district south of the Cauvery. Where hornblendic rocks prevail, the soil shows rapid alternations of red of all shades, some very bright, others toned by an admixture of brown. This is generally the case over the whole of Salem district, so far as it has come under survey. The presence of magnetic iron beds renders the soil generally of a very dark red or reddish-brown. Talcose-schist, such as occurs largely in the southern part of the Baramahal, near Huroor, is covered ordinarily by a rather pale red soil. The coarse quartzo-felspathic granitoid gneiss of South Arcot yields nearly pure sand of very pale reddish colour.

Torrent mounds.

A formation of some interest, which may be observed in many of the mountain valleys of our area, may be here very appropriately considered. The formation in question consists of an assemblage of numerous large and irregularly-shaped mounds of red sandy loam, with here and there small particles of kunkur; the mounds often occupy both sides, and in other places one side or the middle of the valleys in which they occur; occasionally they alternate from side to side down the course of the valley. Such mounds may be seen to the greatest perfection, perhaps, in the pass which divides the

Tainandamullay from the Karapaudymullay. They stretch across the valley from side to side a little to the west of the village of Combaly. (Cuppaly of map.)

Thickness of soil.

The thickness of the red soil which towards the bottom shows some few imperfect layers of rounded and partially rounded pebbles, is very considerable, a depth of not less than 40 or 50 feet being exposed in some of the stream sections.

These red-soil mounds are generally overgrown with the ordinary forest trees of the neighbourhood, which with the grass likewise growing on them, greatly diminish the erosive action of the rains. As soon as roads are cut through the forest, or the protecting agencies otherwise removed, the waste of these mounds under heavy rains is shown, by the deep scorings they bear, to be exceedingly great. Other fine examples of such accumulations of red soil may be seen in the great valley running into the Tainandamullay range from the south and dividing it into two parts. In this valley near the village of Perryagoody Muddavoor such mounds occur on both sides of the river (the Vellaur) in such form as to prove conclusively that the deposit was at some past time much more extensive than at present.

At the mouth of the great ravine opening on the north side of the Tainandamullay at Taultooky, (a village 4 miles south-west of Combaly,) a very great accumulation of red soil has taken place, and appears to rest in part on an immense bed of boulders and other blocks, which show very strikingly the immense grinding and crushing force at play when the ravine torrent is in freshet. The red soil is accumulated here almost to as great a thickness as at Combaly. A much smaller example of these red soil accumulations occurs in the valley east of the great north spur of the Surragoomullay, south-east of Salem. The accumulation of soil has taken place chiefly in a narrow part of the valley, which is bounded on the west side by the great spur above referred to, and on the east by a smaller series of hills not indicated on the maps. The

principal soil mound is cut through by the torrent coming down the valley, and has two good sections, of from 20 to 35 feet in thickness, of the red sandy loam thus exposed.

In the middle of this section, on the northern side of a bend of the stream, numerous fossil fresh-water shells are found, all belonging to existing species of the genera *Melania*, *Planorbis*, and *Lymnea*. The shells are in a very brittle condition, and difficult to extract entire.

Other remarkable accumulations of the red sandy soil in mountain valleys occur in the great Toombay and Muttapary valleys, on the east side of the Kalroyen range. On a lesser scale as to size, but very characteristic in form, are the accumulations met with in the horse-shoe valley which opens to the north-east in the Kolymullay, a group of low hills due south of the Godumullay. Here the thickness of the soil is less remarkable than the great number of mounds into which it has been worn by long-continued pluvial action. The same may be said of the last of the accumulations we will mention, *viz.*, one occurring in the small valley formed by two ridges of no great elevation, which lie between the great Periacombay valley and the main stream of the Peryaur, which rises on the northern end of the Kolymullay range.

In the Kalroyenmullay.

These remarkable heaps of soil would appear to have been formed originally by the combined action of the torrents traversing the valleys in which they occur, and of heavy rains washing down prodigious quantities of soil from the mountain sides, at a period when the annual rain-fall probably far exceeded that at present occurring on this part of India.

There appears to be further evidence of this having been the case in the dimensions of the beds of some of the torrents on the mountain sides, where blocks, which were at one time constantly exposed to the action of the stream, as shown by the polishing and scratching of their surfaces, are now but rarely, if ever, touched by the water, and are greatly

covered by lichens of various colours, and without any signs of water-marks, which these turbid streams leave very distinctly.

The dam-like accumulations, as, for example, those of Combaly Pass and at the mouth of the Taultooky ravine, may not improbably have been formed by the torrents having been actually ponded back either by some landslips or by some large masses of rock in course of transport being brought to a stand-still by some impediment, or having reached a point beyond which the pressure of the stream was insufficient to move them.

The materials brought down subsequently would then be deposited behind and above them, so that, under favorable circumstances, the stream might be fairly dammed back till the weight of water behind the dam sufficed to produce a debacle, or the water found some other outlet. In a lake thus produced, a deposit of great thickness might soon be formed by the joint action of the torrent and of the rain falling on the slopes above the dam. Any cause subsequently arising to breach the dam would immediately set up a current, which would cut deeply into the deposit formed behind the dam, and these currents, aided by heavy rain-fall, would tend to form the strange mounds above described.

Sufficient evidence was not obtained in any case to be able directly to attribute these phenomena to the cause above supposed, or to any other; but the above seems the most likely. No traces of any fossil whatever were met with in any of these deposits, except in that north of the Surragoomullay, on the banks of the Adagaripully nullah above described. The soil of these valley accumulations is a red loamy sand, generally rather less ferruginous than the ordinary red soil of the low country, and not remarkable for its fertility.

The admixture of kunkur already referred to is occasionally so great as to solidify the whole and form a peculiar deposit, which has already been described when treating specially of that form of limestone. Of the very sandy reddish soil covering the country where the granitoid gneiss rocks occur, nothing more need be said than that it would appear

to be almost entirely formed by decomposition of the quartzo-felspathic rock *in situ*. It contains occasionally scattered pellets of laterite character, probably resulting from the decomposition of grains of magnetic iron dispersed at rare intervals through the parent rock.

Origin of Lál.

Of the origin of the red soils, we can say but little; a great part, and probably by far the greater part, is formed from the decomposition of more or less ferruginous rocks, especially the hornblendic varieties. Mr. Blanford considers them to have been chiefly formed in or on the sides of lagoons,—a supposition which does not, however, appear to us to be borne out by the facts of the case generally, though to certain beds of limited area such an origin may be attributed.

The red soils occurring on the several ranges of mountains which are evidently formed by weathering of the underlying rocks, cannot be distinguished by the eye from the *Lál* of the plains, and in both, the variation of the amount of ferruginous matters may be constantly seen to be dependent upon the nature of the underlying rocks.

II. Second in importance in point of area are the *alluvial soils*, which have, however, already been described in full in the IIIrd Chapter as members of the youngest of the Geological systems found within our area of report.

Cotton-soil.

III. *Black soils.*—Cotton-soil (or Regur) as the name implies is one on which cotton is grown. But it does not follow that this vegetable product is only grown on such a soil; indeed, it is, in the districts treated of, oftener and better cultivated on a dark grey soil, in which there is a considerable amount of calcareous matter (kunkur). The Regur, which is known to the Tamulians by the name of "*Karuppu-man*" (black soil), and to the Telugu-speaking Hindoos by the name of *regada*, (a soil identical with that of the Dhoor plain, Cuddapah district, which is one of the typical *cotton-soil* areas in south India,) covers considerable areas of the country we are dealing with; the largest unbroken or nearly unbroken spread occurring in the southern

part of South Arcot. This spread, or, to speak quite correctly, this series of closely contiguous spreads of generally dark black cotton soil, occupies the greater part of the open country between the Vellaur river on the south and the Kullakurichi river on the north. On the west the cotton-soil stops short a few miles east of the mouth of the Ahtoor Pass, and on the east it dies away or passes imperceptibly into the old alluvium of the valley of the Vellaur and Munnimootaur rivers.

Regur north of the Vellaur,

In the neighbourhood of Volcondapuram, there are some extensive spreads flanking the north-east side of the Patchamullay. These spreads were no doubt once continuous with those covering the cretaceous rocks, as well as with those lying between the Ellayaur and Vellaur rivers and the great spreads north of the latter river.

near Volcondapuram:

Cotton-soil is further found to the south of the Patchamullays, where there is a large spread immediately south and west of Chettycolum.

near Chettycolum:

In the Toriore valley (Trichinopoly district), between the Kolymullays and Patchamullays, Regur occurs in several detached and rounded patches near Devaruppunputty, about 3 miles north-west of Cunnanoor, at Okaray and Bandraputty, 4 or 5 miles south of Oopillipooram, and at Amahputty, 3 miles south of Toriore.

in Toriore valley:

East and north of the Tullamullay are several well marked spreads of moderate size.

round Tullamullay;

West of Namcul, in Salem district, we meet with a small spread of Cotton-soil.

near Namcul;

South-east and east of Adamancotta, at the south end of the Baramahal terrace, at an elevation of between fourteen and fifteen hundred feet above sea level, and around Darmahpoor, are several good-sized spreads of typical Cotton-soil, especially to the north of the road from Darmahpoor to Pennagrum.

in the Baramahal;

Eastward of the Mookanoor peak, Cotton-soil is again found, at a very high level,* and spreads, without any important break, as far south as the bend of the Toopoor river. A long strip occupies the northern part of the Munjawaddy valley, and extends northwards along the foot of the Tainandamullays, for 3 or 4 miles.

east of Mookanoor;

Several small but typical spreads of Regur occur in the eastern part of the Salem-Ahtoor valley, and also in the great Cottaputty valley which divides the Kalroyenmullay from the Tainandamullay.

A considerable area of the Kullakurichi Talûq northward of the town is covered with Regur.

Detached spreads extend a few miles northward from the Munnimootaur, along the eastern boundary of the metamorphic rocks.

Lastly do we meet with a very extensive and typical Cotton-soil area north of the Ariankoopum river, which Mr. Blanford considers to be continuous with the Mercanum black soil swamp.

near Pondicherry.

The very black soil lies, as far as we have seen, on the higher undulations of the comparatively flat country. It is generally of a very dark brownish-black colour, with occasionally greyish or blueish shades. The mineral composition of Cotton-soil varies considerably, some varieties being so sandy as to constitute a clayey loam, while others are marly, or still more rarely form a very stiff clay, all agreeing, as a rule, in the absence of coarse mineral particles.

Varieties of Regur.

In dry weather the surface is seamed with gaping cracks, which break it up into irregular polygonal figures, and the soil is then very friable, but in wet weather it becomes a highly tenacious mud.

Many of the larger cracks extend 3 or 4 feet in depth, and where numerous, render the ground unsafe for rapid riding.

* Mullapooram Railway Station stands 1,413 feet above sea level.

According to existing chemical analysis, there is very little organic matter in this soil, the mean result of observations being about four per cent. "M. D'Archiac quotes the following analysis in his *Histoire des progres de la Geologie*" (Vol. II, page 329), but without stating from what part of India the sample in question was derived :—

Silica	48·2
Alumina	20·3
Carbonate of lime	16·0
„ of magnesia	10·2
Oxide of Iron	1·0
Water and organic matter	4·3
	100·0

In appearance the Cotton-soil bears a strong resemblance to the black soil of the Nilghiris, of the Anamullay forests, and of the 'bottoms' and parts of the surfaces of peat bogs in Ireland. It is also very like in appearance, and probably of similar origin, to the black mud soils at present forming on the beds of most tanks and jheels and of some of the back-waters of India.

Resemblance to other soils.

Looking at the Cotton-soil, then, as compared with these soils, we are inclined to regard it as a sedimentary deposit mixed with organic matter, chiefly vegetable in its origin, and we further believe the deposits to have been formed more generally in fresh than in brackish waters.*

The black soil, or 'Maiden earth,' which is formed on the surfaces of peat bogs in Ireland, contains very little organic matter, and is derived from the peat through the exposure of that deposit to atmospheric influences, when the organic matter is decomposed by the liberation of the carbonic acid.

Maiden earth of peat bogs.

* Mr. Henry F. Blanford has already put forward the idea of this soil being mainly of Lagoon origin.

Black soil of the Nilghiris,

The fine black soil just on the surfaces of the peat bogs and drying-up swamps at the bases of many "sholahs" (woods) on the Nilghiris, is undoubtedly formed in the same manner.

of the Anamullays.

In the dense damp forests of the Anamullays, south of Coimbatoor, the black soil is still a highly vegetable one, owing to so little exposure to weathering influences.

Mud of tanks, &c.

In tank beds and jheels of India generally, there is possibly more of animal life going on; but there is at the same time quite sufficient vegetable life to yield the amount of vegetable organic matter necessary for the production of this soil, and, above all, these localities are exposed to atmospheric influences far more powerful than is the case with the peat of Ireland, or of the Nilghiris.

Atmospheric influences instrumental.

It is the intensification of the weathering influences of the Indian climate which appears to us to be the great agent in the production of this soil, and which accounts in great measure for the almost total destruction and consequent absence of all organic remains in recent deposits where we know that life has been so largely developed.

Back-water deposits not generally productive of regur.

We have seen numerous instances of back-water mud which is now dry land, and which has not turned to Cotton-soil, and this is in all probability owing to vegetable life having been so sparingly developed in it. Should the back-water area become subject to fresh water inundations, there would then be an opportunity for the development of vegetation to a sufficient extent, and this has probably been the case with the Mercanum area referred to by Mr. Blanford in his Memoir on the Cretaceous Rocks of Southern India.

Mercanum back-water, essentially fresh water.

The Mercanum area was once a back-water, but is now, if we are not mistaken, cut off from the sea by a permanent bar, and periodically inundated by fresh water. It is along

the inland shores of this lagoon, which is sometimes, if not always, filled with fresh water, that regur-like soil is now forming.*

It is evident from the above that shells might be expected to be found in undoubted black lagoon mud in some cases, though rare in the Chilka and Negombo lakes, cited by Mr. Blanford.

High level spread of regur.

Another argument in favor of the fresh water character of the regur-depositing waters may be drawn, and apparently with good reason, from a consideration of the various levels at which the Cotton-soil occurs. It has already been observed (see page 132) that spreads of regur occur at comparatively great elevations above the level of the Indian Ocean; as, for example, at Adamancotta, Darmahpoor, and other places in the Baramahal, and to the west of Namcul, in the low country.

In the first cases, if the plains around Darmahpoor and Adamancotta had become covered with regur, through the existence of brackish water

* Since our examination of the Cotton soil of the south, I have seen the greater part of the Nellore coast, in which is included nearly the whole of the Pulicat lake, and though there is evidence of a very considerable area of back-water alluvium, which is now dry and cultivated land, I have seen no true Cotton-soil, though there is an approach to it, while the back-water alluvium differs from that of the rivers (which is generally a pale sandy deposit) in being dark coloured and humic. The only approach to a black soil like Cotton soil appeared to me to be forming in two long parallel fresh water jheels between the Soornamookey and Kistnapatam, and similar swamps thickly covered with screwpine (Pandanus) and Rattan jungle on the long sandy spit which forms the eastern shore of the Pulicat lake. The dried up parts of this lake show a dark grey calcareous mud, with remains of estuarine shells.—W. K.

The dark coloured clayey or sandy and clayey mud turned up in various parts of the Covelong back-water (in digging wells whence the brine is during the dry season pumped into the salt pans) abounds generally in sub-fossil shells of existing marine and estuarine mollucca. This dark clay and the shells are met with at frequent intervals between Covelong and Madras, as shown by the soil turned out in digging the canal to Sadras. Both the clay and the shells are also to be met with under various parts of Madras in sinking for water, which is almost invariably of bad quality when it has to traverse the black clay.—R. B. F.

lagoons connected with the sea, as those of Mercanum or the Chilka and Pulicat lakes, it is evident that the whole of the low country of our area must have been under the waters of the sea in question, out of which the Shevaroys and other mountain ranges would alone have risen as islands. No indications remain of such a state of things, and there is good reason for believing that no such great depression of the metamorphic country has taken place since it acquired its present general contour. If such a sea ever did surround the mountains and highlands, it must have been at a period subsequent to the formation of the Cuddalore sandstone series; unless we presume the regur to belong to more than one geological period,—a presumption not warranted by our present knowledge of the facts connected with the several formations of Cotton-soil before enumerated. Supposing such a sea to have existed, the question at once presents itself, what has become of the sedimentary deposits, both littoral and pelagic, formed by it? We can hardly suppose that they would all be so utterly swept away by denudation as not to have left any traces whatever among the numerous and often very tortuous valleys of the mountain country. We cannot, then, attribute the formation of the Darmahpoor Cotton-soil to the action of brackish water lagoons connected with a sea washing over great part of what now forms the Baramahal, but must suppose the regur to have been deposited in shallow fresh water lakes, or, if the water was not fresh, the saline properties must have been derived from the decomposition of the metamorphic rocks of the neighbourhood in which the deposit took place. The same argument will apply to the other high level regur deposits of the Baramahal, and also to those in the neighbourhood of Salem, but not so forcibly to those occupying lower levels nearer the coast.

The position of the cotton-soil spreads which we have enumerated, in so far as they are comparatively elevated, would seem to indicate shallows in the then inundated country, which would be the sites of vegetable life, while the adjoining spreads of dark coloured calcareous soil

look like areas which have been tenanted by animal life solely, or to the greatest extent.

Agricultural value.

Regur is principally devoted to the cultivation of cotton and other dry crops, but experience shows that the most luxuriant crops are not raised on the very pure or black variety, but rather on a soil of medium quality, in which kunkur particles are distinctly visible, and which is of a blackish-brown or blackish-grey colour. This fact is recognized by M. D'Archiac in his *Histoire des progres de la Geologie* (Vol. 2, page 329), in which it is stated that cotton-soil is fitter for cotton cultivation in proportion to the quantity of lime which it contains.*

Mixed soils.

IV. The least important of the four classes of soils we have defined is that of the *mixed soils* which occupy a small area, comparatively speaking, in the country we treat of. We include in this class the various transitions between red, black, sandy, and white soils and vegetable mould.

These transitions are generally met with at the borders of great spreads of the several pure soils which commonly appear to graduate into each other, a process greatly assisted by the turning up of the soils in agricultural processes.

In many cases the transition is very gradual and insensible, and it is often very difficult to decide what to consider as an impure variety of a pure soil, or what to class at once as a mixed soil.

In connection with the regur, two classes of mixed varieties may be established.

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* This may possibly be, to some extent, connected with the fact before adverted to, of the blackest and purest regur occurring at the higher levels, and being therefore not so well situated for retaining the requisite amount of moisture. Where brought under irrigation, the black soil always appeared to me to be highly productive.—R. B. F.

First.—Soils of organic origin, in which animal life was more

Mixed regur soil.

valent than vegetable life, as proved by the e
sive quantity of kunkur formed by decompo
of shells, &c., and subsequent precipitation of the carbonate of
derived from them.

This class is one which undergoes many changes in its compo
and texture, according to the greater or lesser amount of kunkur p
cles which may be distributed through it, becoming of a light gre
even whitish colour.

Secondly.—We find soils of an origin only in part organic, w
assume a dark brown or reddish tinge, owing to the admixture of ferr
nous matter derived from the rock in the immediate neighbourhood.*

Some of the transition soils are of great fertility, especially the
chocolate-coloured loams met with at the junction of rich red soils
black soils.

The most barren of all the soils is the white or salt soil, general
mixture of clay and sand in variable proportions, containing consider
quantities of both soda and potash, together with some common s
These salts are derived from the decomposition of the highly felspat
rocks in the neighbourhood.

This white soil is generally met with in hollows or swampy pla
and often contains small but troublesome quicksands.

On the south bank of the Cauvery, there are several spreads of
white soil, where large nullahs which have had a rapid course over

* In the valley of the Cauvery, south of the Patchamullays and Kolymullays, t
appears to be some connection between the dark coloured soils (not Cotton-soil) and the r
they overlie; for here I observe that these soils are spread over so much of the
country of this valley as is formed of frequently alternating beds of gneiss, schist,
hornblende rock. These rocks lie along the north side of the Cauvery valley, in which
wide spreads of dark soils, which are rather like Cotton-soil, and the same rocks occu
the south side of the valley, just at the edge of our area, where the very same kind of
again appears.

different beds of the metamorphic series suddenly come upon nearly level ground near the edge of the alluvium.

The white soil occurs in many places all over the country, but the spreads are very rarely of sufficient extent to be worthy of notice.

Most of the streams show that their waters hold alkaline salts in solution by depositing a white efflorescene on their banks by evaporation. Further on (see chap. on Economic Geology) a description is given of the method adopted by the natives to obtain the salts contained in these white soils.

Rarity of marls.

As might be expected from the very trifling amount of limestone occurring within the country we are dealing with, true marls are almost unknown, unless some of the kunkury varieties of Cotton-soil be regarded as such. If this be done, they are not uncommon in the regur-covered districts before enumerated.

NOTE.—As illustrative of the great variation in the composition of 'regur' or cotton-soil generally (see p. 133), I give below the results of analyses of several specimens from different points in the Nerbudda valley districts, all taken from localities well known as good and richly productive Cotton-soils.

Of the seven analyses here given, the first two, numbered respectively A1, A2, represent the surface soil and sub-soils taken from the same locality, A1 being the surface, A2 from 5 feet below surface. The two marked B1, B2 are in like manner the soil and sub-soil (3 feet deep) from one locality, while C, D, and E are the soils taken from only a few inches below the surface. B1 is considered the best quality of soil.

	A.		B.		C.	D.	E.
	1	2	1	2			
Insoluble	62·7	47·61	62·8	63·7	68·61	57·91	61·80
Organic matter	9·2	8·4	9·0	8·7	7·2	8·7	7·65
Water	8·4	7·6	8·2	6·5	9·4	9·9	7·35
Oxide of Iron	11·0	15·9	10·9	11·4	6·76	4·36	5·7
„ Alumina	7·5	8·6	7·6	8·4	5·81	8·75	7·67
Carbonate of Lime	1·2	11·89	1·5	1·3	1·57	9·28	8·53

The residue in all consisted chiefly of Magnesia and Alkali; in A1, B1, and B2, there were traces of Sulphuric Acid.

A and B were from near Seoni, C from Indore, D from Burwani, and E from Boorhampore.

The analyses were made by Mr. A. Tween in the Laboratory of the Geological Museum, Calcutta.—T. OLDHAM.

CHAPTER VII.—*Physical changes now in progress.*

The changes which the earth's surface is now undergoing daily must not be left out of consideration, in treating of the general features of the country; although in inland districts, as a general rule, (to which, however, volcanic regions form an important exception,) the changes of feature are so slow and gradual as not to fall under the observation of passing travellers, nor indeed do they often strike the eye of observing residents; of so trifling a magnitude are they in general.

Land slips and the shifting of river channels are the most important changes, in a geological point of view, which are observed in inland provinces. But if some of these changes of physical aspect are uncommon inland, they are by no means so rare on exposed coast lines, (as on the portion of the Coromandel Coast extending from Pondicherry to Negapatam,) for here the alterations of feature are in many places apparent to any observer.

Here a constant strife is going on between sea and land, in which the former is invariably victorious in the long run, and encroaches on the boundaries of its opponent in a ruthless manner, demolishing in its course

Inroads of sea at Tranquebar

any works of man which it may find. Ample evidence of this may be seen at Tranquebar, which town seems to have suffered more than any other along the coast from marine inroads.* But for the stone groynes or break-waters thrown out by order of Government, the citadel and town would, in a few stormy seasons, be washed down by the rains.

The encroaching action of the sea has been going on at intervals

in 1755;

for a longer period than can be traced in history. In 1755 the Danish Authorities applied to the 'Tangaur' Rajah for an extension of territory, a very large portion of the fort having been washed away by the sea. (See "An account of the war in

* For full information about these, see various papers by different Engineers in the Reports of the Madras Engineers for 1856.

W. King del.

P. L. Fraser lith.

PAGODA on the Coast at TRANQUEBAR
shewing inroad of the sea.

India from 1750 to 1761," by Richard Owen, Cambridge. London, 1762, page 131.) By referring to the very interesting "Reports of the Madras Engineers" above quoted, it will be found that during the north-east monsoon of 1849, the coast suffered at Cauverypatam; also at Negapatam, where part of the Coopum or fishing village was washed away; and at Tranquebar, where the sea encroached two yards on the land.

in 1849;

Again at Tranquebar in 1853, during a hurricane, two houses were destroyed, and the custom house on the beach outside the citadel injured by the violence of the waves, and further, between the month of June and the end of that year, one of the groynes and part of the fishing village. It is also mentioned in the Reports, on the authority of Colonel Götting, Danish Engineer Officer, and fifty-six years' resident in Tranquebar, that one or two hundred years back, the beach extended 4 or 500 feet beyond the present line of sea-walls, and that at a still later period, a battery stood 300 feet further out than the existing walls.

in 1853.

Fronting the sea between the King's and Queen's bastions, stands a good-sized pagoda, which has suffered much from the heavy surf during storms. During the last 20 years, the sea has undermined and swept away the building for a distance of not less than 50 yards from its former seaward limits. The annexed sketch (Pl. IV.) shows its condition in August 1859, the east front of the Goparum or gate-tower having fallen down.

This rapid wearing of the beach at Tranquebar is attributed to the fact that the sands rest on a bed of clay, and to the more directly vertical action of the waves here than elsewhere; also to the peculiar set of the currents; confirmatory of which is the fact that the mouth of the river Mundalaur, south of this place, as well as the rivers entering the sea at Negapatam and Tirmellwassel, are shifting in a northerly direction. This action would also

Coast currents.

account for the northerly inclination of the lowest reach of the Coleroon river, the sand carried out being constantly spread north by the up-coast current.

These currents, full particulars of which we have not been able to obtain, are in great measure dependent, for direction and intensity, on the prevalent monsoon; but the southerly current which comes in from the Indian Ocean through Palk's Straits, seems to be the more powerful, if we may judge by the direction pointing to the north, in which the spits of sand at the mouths of the Mundalaur and Coleroon lie.

At Porto Novo and Pondicherry.

Of the wear and tear of the coast at Porto Novo and between Cuddalore and Pondichery, we have not been able to obtain any reliable or detailed information, but at the latter place the sea has made considerable inroads.

Of changes of physical feature artificially brought about, none is more note-worthy than the formation of local alluvial deposits at any possible level, owing to the extensively practised system of throwing bunds or dams across rivers and streams for the purposes of irrigation,—a practice which adds not a little to the difficulties of drawing a well defined alluvial boundary, already adverted to, rendering it necessary always to follow the course of the stream under inspection in an upward direction, in order to meet the first dam by which an artificial alluvion at a higher level may have been formed.

Alluvium from artificial causes.

The difference of level, and consequently of horizontal extension, is very considerable when large bunds have been raised, as, for instance, on the main western tributary of the Iyaur, about 2 miles south-east of the village of Mungalum. Here, a large bund now burst had been thrown across the river, by which, on the upper side, a tract of a dark friable alluvium, like Cotton-soil, several hundred acres in extent had been raised from 4 to 8 feet or more above the surface on the south side of the bund. In the channel of a nullah flowing into the river on the east side, just above

the old dam, a section is shown, in which the artificial alluvium is seen to be underlaid by a grey soil with some kunkur and numerous dead specimens of the existing river shells, as *Corbicula consobrina, Unio, Melania, Paludina, Ampullaria*, &c.

Below the bund this grey bed is overlaid by a very thin layer of darkish soil a few inches thick. Underlying it is a greyish-white soil, abounding in masses of kunkur, and containing apparently no shells whatever.

Great dams like the annicuts over the Cauvery, Coleroon, Vellaur, and Punniar cannot but greatly affect the direction and degree of scouring action exercised by these several rivers, even to the extent of greatly modifying their channels in the lapse of several years.

Earthquakes.

Of causes tending to change the surface of the country, we must not forget to mention earthquakes, by which the neighbourhood of Salem has been from time to time shaken, although not sufficiently to produce the overthrow of any buildings.

Two shocks were experienced by us; the first in January 1860, when at Macdonald's Choultry, a few miles south-west of Salem. The vibration was hardly perceptible, but the subterranean noise was very strong, and strikingly like the rushing of a heavy cart on a hard road. The sound came distinctly from the east, and died away in the west. We subsequently ascertained that the inhabitants of Salem and of the Shevaroys had, at distances of 12 and 20 miles respectively, been disturbed the very same evening by a smart and very perceptible earthquake shock.

The second was felt at Careputty "Travellers' Bungalow," 8 miles east of Salem, in the forenoon of April 12th, 1861. There were two smart explosive upward shocks, accompanied by a loud noise, like the report of small cannon. The shocks shook the Bungalow sufficiently to make the rafters of the roof crack very audibly. The noise, which was dis-

tinctly subterranean, died away in the direction of Salem, but was not perceived there. Enquiries made immediately after proved satisfactorily that the explosions could not have been due to any thing but an earthquake, which was the impression they instantly made on the mind.

Another shock was noticed in 1861, in Salem district, but not by any member of the Geological Survey. Some of the natives at Careputty were rather alarmed by the loud subterranean explosions, which seemed new to them.

CHAPTER VIII.—*Economic Geology.*

No one can have travelled through any of the districts of Southern India in which large pagodas occur, without having been struck by the admirable adaptation to architectural purposes of several varieties of gneiss rock, as regards both the size and the durability of the blocks employed, independently of their beauty when polished.

To cite only a few examples in well-known and easily accessible places. In the Durbar hall in the Rajah's palace at Tanjore is a magnificent slab of gneiss, raised some height from the ground, and supporting a fine white marble statue (by Chantrey) of the late Rajah, in lieu of the throne which formerly occupied the slab. The dimensions of this splendid slab are:—length 18 feet, width 16 feet, depth 2 feet 1½ inches. The upper surface is polished, and shows well the foliation of the rock, which is a quartzo-felspathic gneiss; but the slab, though well cut, cannot be called well polished, and looks of a dingy brown colour, owing, very probably, to the peculiar method of polishing in use by the natives.

It is not known where this fine mass was quarried, but equally fine masses might doubtless be obtained by skilful workmen from several of the gneiss bosses near to Trichinopoly, which are similar in their mineral composition, such as the Mummullay, near Thoangoody "Travellers' Bungalow;" the Errumbeesprum Pagoda Rock; the Golden Rock or Ponmullay, on the Brigade Ground; and the Trichinopoly Rock itself, in all of which the jointing and foliation appear favorable to the quarrying of large rectangular masses of stone.

Carved stone-work at Tanjore,

The great Bull in the court of the principal pagoda at Tanjore is also a very fine carved monolith, said to consist of black granite or syenite.*

A smaller temple, standing in the north-west corner of the pagoda court, and built of a pale quartzose gneiss, is a perfect gem of carved stone-work, and the tooling of the stone in the most exquisitely delicate and

* At the time of my visit, it was so thoroughly covered over with a coating of red laterite dust mixed with the sacrificial oil, that I could not pretend to say what might be the nature of the stone underneath.—R. B. F.

[redacted]

west of Coimbatoor, have been used by the Engineers of the Madras and Beypoor Railway for walls and other purposes, and appear to have given complete satisfaction. If well selected, they are not only admirably adapted for general building purposes, but could advantageously be applied to decorative purposes, being susceptible of a high polish. The marble must, however, not be polished in the native method, which greatly defaces the stone by choking all the minute cracks between the crystals with a dirty black substance; at least such was the case with specimens which we had cut and polished in Trichinopoly.

The beds at each of the localities enumerated in Chapter IV would, we feel quite confident, yield marbles in every way equal to those of Muddakurray and Sunkegherry Droog, and are well worth quarrying, both for building stones and for lime-burning. In the former capacity, their superiority to bricks is unquestionable, and they are so much more easily and cheaply dressed than any of the siliceous gneissic rocks, that they merit every attention. The beds are, as a rule, singularly free from joints, and blocks of immense size might in many places be obtained with very little difficulty.

As already mentioned in Chapter IV, we no where found the natives using the limestones, even for the purpose of lime-burning, for which object they prefer collecting the common kunkur, so generally distributed over the country. The lime is burnt in little mud-built kilns of elliptical or circular shape, the same, in every respect, as those described by Mr. Blanford at page 208 of his Report.

Lapidaries at Vellum.

One of the minor branches of mineral industry, that of cutting and polishing the varieties of quartz found in the grits of Vellum, has already been alluded to at page 36. The principal varieties of the so-called Vellum stones are the pellucid or rock crystal, the dark brown or smoky quartz, the yellow or cairngorm, and amethyst; these are cut by the lapidaries at Tanjore and Trichinopoly into a variety of ornamental and useful articles. The ornamental articles are chiefly brooch-stones cut in the brilliant, rose, and

other patterns. Among the useful articles may be mentioned watch-glasses and double convex spectacle lenses for old or weak sight. Among some specimens of Vellum stones, cut and uncut, presented to the Museum of the Geological Survey of India by W. M. Caddell, Esquire, the Collector of Tanjore, was a crystal of amethyst, (a six-sided prism, with terminal pyramids,) in which, radiating from the corresponding faces of an internal pyramid, was a brush of small acicular crystals of Rutile. The crystal, which was rather broken at one end, measured one inch in length by 3·5 in diameter.* These pebbles and crystals are most likely derived, in the first place, from large quartz veins in the metamorphic rocks.

Pot-stone vessels.

The preparation of vessels of all shapes and sizes from blocks of pot-stone or compact steatite, has already been referred to (see note, page 102). The vessels are cut by means of various chisel-shaped tools, when resting either on a pad of straw and rags, or else on the operator's lap. The profits seem to be but very small, judging by the poverty-stricken appearance of the workers at Tandacoundenoor, &c., which is due probably to the great number of failures they have to contend with, owing to numerous flaws and impurities in the pot-stone. The manufacture of vessels of pot-stone or compact steatite is also carried on at Yermaputty, a village lying near the western end of the great valley separating the Kolymullays from the Tullamullay. In one pit at this place from which pot-stone had been dug, we noticed a small vein of beautiful dark green crystalline Chlorite. The vein varied from 1 to 4 inches in thickness.

Trappean rocks; uses.

Trap Rocks are, within our area, used only as rough stones for tank-bunds, &c., or as road metal, for which latter purpose they are better than almost any other class of rocks, especially for military and other roads exposed to heavy

* The specimens presented by Mr. Caddell were unfortunately lost in the wreck of the "Aurora."

traffic. In addition to their exceeding hardness and difficulty of working, there is a great objection to their employment as building-stones, namely, that in damp climates the basaltic varieties absorb and retain great quantities of moisture.

Sandstone.

Sandstone quarries came under our notice in one place only, namely, to the north of Verdachellum, in the Cuddalore series of rocks. The generally very friable sandstone is there compact enough to be converted into cattle-troughs, rice-mortars.

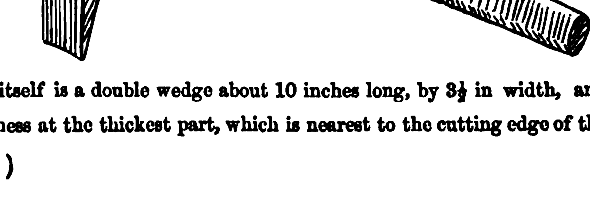
Laterite.

Laterite, if well selected, offers a fair building-stone, and, though apt to wear away soon under heavy traffic, makes a good road material, because of its strong binding qualities. It is quarried in various places for both purposes, especially near Tanjore; for example, along the road from Trichinopoly to Tanjore, and in many of the villages of the detached areas shown in the map.

It is quarried at or a little below the surface, square blocks being picked out with a crow-bar, or the ordinary pick used by the natives,* and then left for some time to become hardened. While being

* At Cottayum (Kotium), in Travancore, an axe of very peculiar structure is employed to cut and dress the slabs of laterite. The head of this kind of axe, instead of having the helve inserted in it, is itself fastened to the helve by means of two rings and a wooden wedge (as shown in the sketch annexed, Fig. 6).

FIG. 6.—AXE USED FOR CUTTING LATERITE IN TRAVANCORE.



The axe itself is a double wedge about 10 inches long, by 3½ in width, and ¾ths of an nch in thickness at the thickest part, which is nearest to the cutting edge of the instrument.

quarried, the stone is sectile, requiring but little trouble in the dressing, but eventually it becomes quite hard. Near Cuddalore and Pondicherry it is largely employed as a road metal.

In Malabar, Cochin, and Travancore, and other parts of the Western Coast, laterite is used most extensively as a building material, and seems to take the place of bricks in every possible way.

It is, from its very vesicular character, but rarely susceptible of any thing like ornamental carvings.

Value of Laterite.

On the subject of the value of laterite as a building-stone, a considerable diversity of opinion exists amongst those well able to form a correct judgment on such a matter; by some its valuė is greatly extolled, by others it is rejected as a very untrustworthy material, on account of its very varying degree of resistance to crushing power.

The fact is, laterite frequently varies greatly in quality, even in different parts of the same bed; hence, in a work in which durability is an object, much circumspection should be used in the selection of the laterite-blocks to be employed, which should be neither very sandy, nor yet wanting in iron.

Where of poor quality, the laterite soon crumbles away when exposed to the influence of weather and moisture, as may be seen in the basement of many of the houses in the Fort of Tanjore. The laterite has there weathered away, leaving the walls perfectly honey-combed, and the layers of mortar, which are more durable, standing out as a regular net-work.*

This, though useful in cutting up the soft clayey laterite, is of little strength when tried against timber. The helve is generally made of Areca or Sago-palm wood.

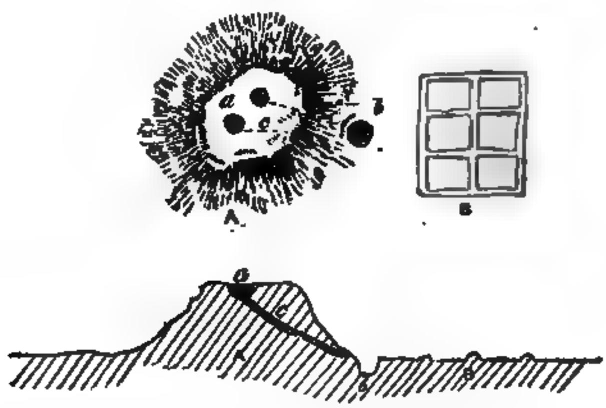
* The laterite in this case was in all probability badly selected, and of too sandy a variety, for in all my subsequent observations of this stone as a building material, it would appear that continued exposure to atmospheric influences, or wet, as in the case of tanks or bowries, only tends to improve the stone. Most of the religious edifices and tanks constructed of this stone show the lines and angles of the carvings as sharply as though fresh from the builder's hands. Laterite is however very absorbent of moisture, and houses built of it ought to be internally lined with cement, or good chunam, a process which is not at all necessary in the use of massive syenitoid gneiss for the same purposes.—R. B. F.

Extraction of alkalies.

The extraction of the alkaline salts from white soil is carried on in various places by the following process. On or near the edge of the more extensive flats of white soil may frequently be seen rudely conical mounds of soil, sometimes single, sometimes also in considerable number, which are employed in preparing the solution from which the salt is crystallized, the process being as follows :—

On the tops of the heaps of earth are one or two basin-like hollows, from which subterranean channels lead down to another basin at the foot of the hillocks, as shown in the accompanying diagram, Fig. 7. The

FIG. 7.—PLAN AND SECTION SHEWING MODE OF EXTRACTING SALTS.



A, raised mound of earth, with (a), basins at top, connected by channels through the mound with the lower basin (b).
B, shallow evaporating pans.

upper basins are filled with the earth containing the salt, and on this water is poured until the salt is supposed to be dissolved out. This liquor is allowed to run by the channels into the lower basin, whence it is drawn and poured into shallow pans made on a flat piece of ground close by, and there allowed to evaporate. After the salt has been dissolved out of the soil, the upper basin is cleared out and filled afresh, while the refuse soil is thrown aside and increases the size of the mass.

Iron.

The manufacture of iron, which has long been carried on with considerable success in parts of the district now referred to, has frequently been described by previous writers,

and it will not be necessary to do more at present than briefly to refer to one or two peculiarities of local interest.

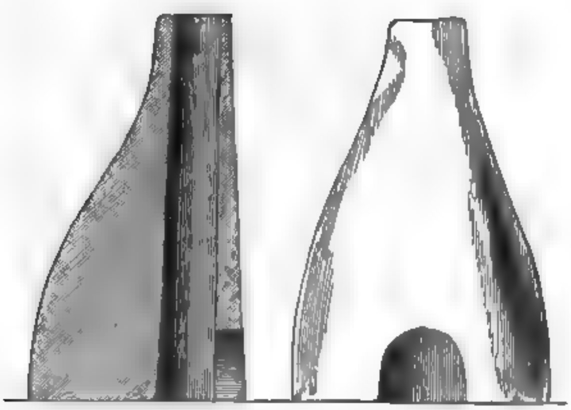
Mode of smelting.

The method of smelting is here, as in other places, very simple, and the apparatus used very cheap. The iron produced is of excellent quality, but the quantity is but small. The consumption of English-made iron is large, and is increasing, for not only is the demand for iron increasing, but the amount manufactured in the district is decreasing from various causes.

Form, &c., of furnaces.

The shape and construction of the furnaces vary slightly, but that most generally used is nearly cylindrical, tapering into an irregular cone at the top. The furnaces are constructed entirely of red-clay mixed with sand; they constantly require to have the inside renewed by fresh linings of clay, which cannot stand more than three or four days' working. The height of the furnace varies from 3 to 5 feet, with a diameter of the interior of from 9 inches to 1 foot. The furnace itself at the ground is about 2 feet wide, and tapers sometimes from the ground, sometimes from about ⅓rd or ¼th of the height; the walls are from 4 to 6 inches thick. The front of the furnaces is for the most part nearly vertical, the back therefore slopes considerably more than do the sides, as shown in the annexed figure,

FIG. 8.—SECTION AND ELEVATION OF NATIVE IRON FURNACE.



giving a section of an iron furnace at Chaindanumgalum, in the Namkul Talûq. (Fig. 8). In some cases, however, the furnace is a regular cone.

Inside the furnace the ground is generally excavated to the depth of about 1 foot, to form a hearth for the bloom. A semi-circular opening from 1 foot to 14 inches high is either left in the front wall, or is subsequently cut into it while the clay is still moist. This is filled up with clay before the commencement of each smelting.

Blast.

The blast required for the smelting is obtained by using two bellows, each made of a sheep or goat's skin, and worked by hand in the ordinary way by a man squatting in front of the furnace. The nozzles of the bellows are made either of thin sheet iron, or tin plate, or sometimes of bamboos, and these are inserted into a clay tuyere entering at the bottom of the front opening, and carefully luted. The tuyeres reach to the centre of the furnace. The bottom of the furnace is covered with a layer of charcoal dust, to prevent the adhesion of the bloom. By using the bellows alternately, a tolerably continuous blast is produced.

Charge of furnaces.

The furnace is first filled to the top, or very nearly so, with charcoal, which is ignited by means of a burning ember passed through the tuyere. As soon as flames issue from above, a small charge of the powdered iron ore, well moistened to make it cake together, is introduced through the apex and covered with charcoal; this is followed by successive charges of ore and fuel, until the proper quantity of ore is in the furnace. The blast is now strongly applied, and continued from two and a half to four hours, according to the size of the furnace. The process is then considered complete, the semi-circular aperture in front of the furnace is opened, and the bloom is removed. A number of heavy blows with a hammer or mallet are given to knock off as much as possible of the adhering oxide, and the bloom is then cut half through with a hatchet, and allowed to cool. The object of cutting open the bloom in this way is to exhibit the grain to the purchaser.

Fuel.

Charcoal is the only fuel used, but different values are attached to different woods for the purpose of charcoal, and frequently two or three different kinds are used at different levels in the

furnace. What the effect of this may be cannot be clearly stated. No flux is used.

Flux.

The ordinary charge for one of these furnaces is about 18 lbs. of ore, and the smelting occupies two to three hours. The average outturn is three blooms in the 12 hours, four men being required to work the furnace; but the furnaces are never worked continuously. In some parts, larger furnaces are used, and the charge for each smelting amounts to 35 lbs. of ore.

Refining.

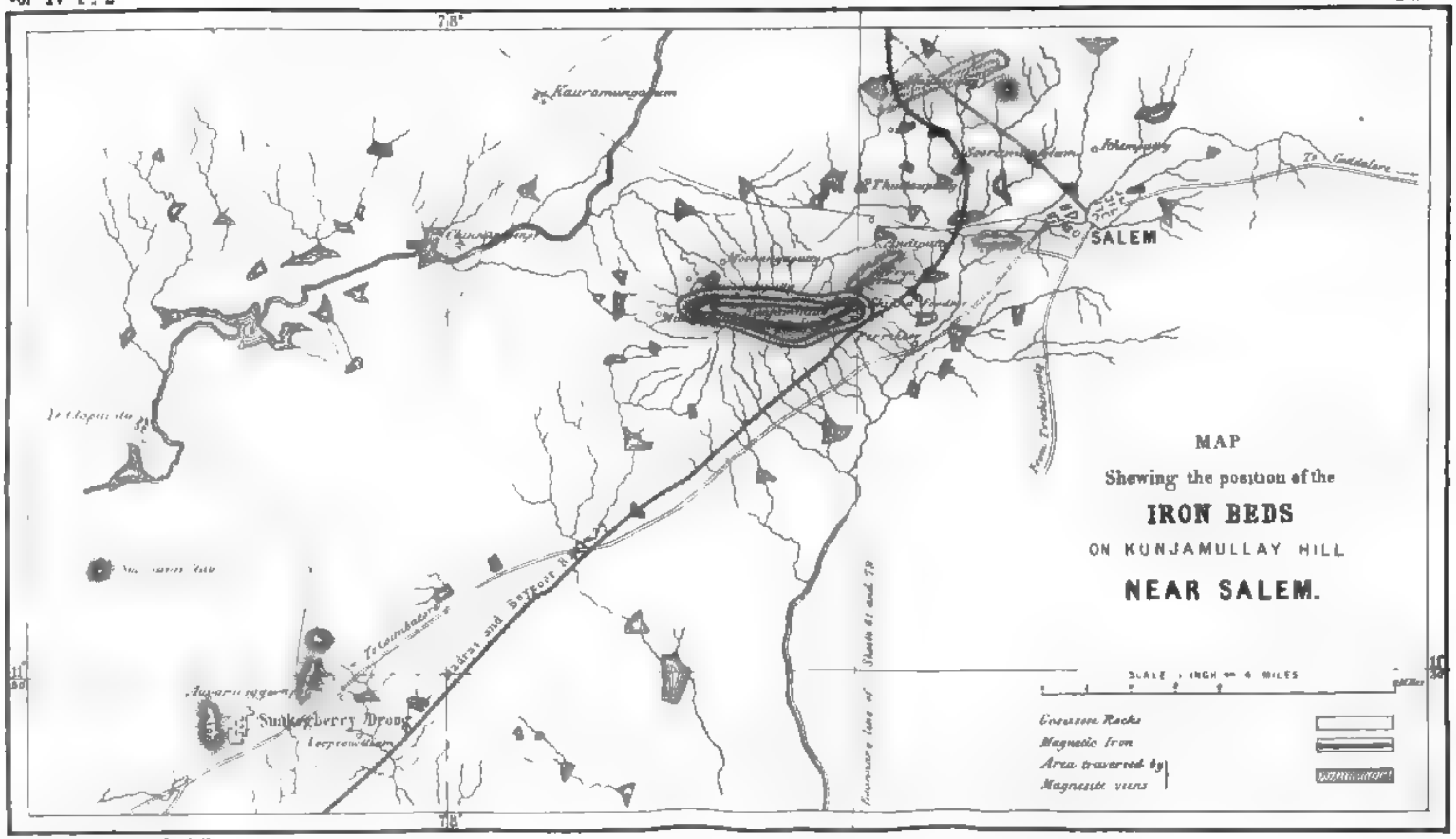
The process of refining the metal thus obtained consists merely in heating the bloom several times, and subjecting it to a good hammering, by which the slag is in great measure got rid of. It is then hammered into rude bars about 1 foot in length and about 2 inches in width. From these bars the 'Wootz' or Indian steel is prepared. Of the processes Mr. Heath has given a very good account in the 5th Volume of the Journal of the Royal Asiatic Society.

The best iron is said to be made near Ranseporum, where the richest ores are worked, obtained from the Kunjamullay, and the great iron bed of the Vailoocoorchy hill. The talûqs of Ahtoor, Namkul, Kistnagherry, Sunkegherry, and Salem are those in which the largest amount of iron is made.

Amount of iron made.

We have already noticed that the manufacture is decreasing, chiefly in consequence of the great increase in the price of charcoal, owing to the serious diminution of the forests under the wasteful practices of the natives; and also to the great general increase in the price of all necessaries of life, which has compelled many to give up the trade of their forefathers for more lucrative employments; and also in consequence of the increased facilities in obtaining English iron, since the opening of the Railway. In 1860 a Moturpha tax of Rs. 1,210-12-7 was raised on 775 furnaces, while in 1859, 928 furnaces yielded Rs. 1,451-1-7.

Vol IV Pt 2 GEOLOGICAL SURVEY OF INDIA. Pl. V.



APPENDIX.

On the Magnetic Iron Ore of KUNJAMULLAY, *near* SALEM, *South India.*

Salem being now within a day's journey of Madras, and its neighbourhood being therefore easily accessible, we may take this opportunity of noticing some very valuable beds of magnetic iron ore occurring in the immediate vicinity of the town of Salem, and almost in contact with the Railway.* These beds are situated on and around a fine isolated mountain called Kunjamullay, which lies about 6 miles to the west-south-west of Salem town.

The summit of Kunjamullay, which is situated in latitude 11° 36′ north, and longitude 78° 7′ east, is nearly the central point of a fine lofty ridge rather over 4 miles in length in an east to west direction, and attains an elevation of about 2,000 feet above the sea, and of 1,000 above the surrounding plain.† Around this ridge the several beds of magnetic iron ore form, in plan, very elongated and somewhat irregular concentrical ellipses, the major axis of which is parallel with, but lies a little to the north of, the ridge as shown in the annexed map, (Pl. V.)

The very distinctly bedded rocks composing this mountain mass belong to the great gneissic rock series of Southern India, the whole of which has apparently undergone great alteration since the period of deposition, and may hence properly be looked upon as metamorphic rocks. Of those in the adjoining area we have given a detailed notice above.

An exact section, showing all the various beds, could not be obtained, for, although the several beds are very well marked, they are generally

* As these iron beds lie within Salem district, they of course come under the lease-rights of the Porto Novo Iron Company, which extend also over the four districts of *South Arcot, Coimbatore, Malabar, and South Canara.*

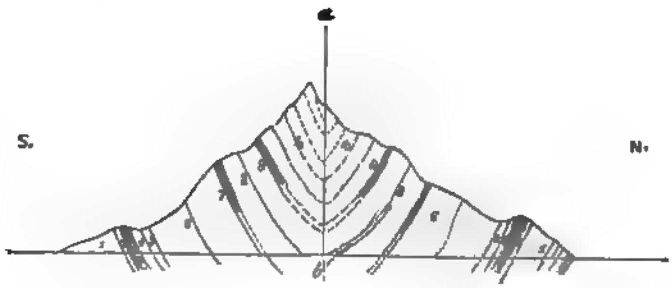
† The Railway Station at Sooramungalam has been ascertained by levels taken by the Railway Engineers to have an elevation of 914·64 feet above the sea at Beypoor.

[redacted]

much covered up by debris and jungle, while the impossibility of ascending and crossing the ridge in a direct line, owing to its precipitous nature towards the top, exposes the observations to the possibility of the same bed having been reckoned more than once.

The following approximately accurate list shows the observed sequence of the beds from below upwards :—(Fig. 9.)

FIG. 9.—SECTION OF KUNJAMULLAY HILL.



a, b, axis of synclinal.

1. Garnetiferous gneiss.
2. Thin Talcose-schist bed, much indurated.
3. Iron bed (No. 1).
4. Hornblendic gneiss.
5. Talcose-schist, highly indurated.
6. Alternating Quartzo-hornblendic and Hornblendic beds, followed by beds of Quartzo-felspathic gneiss (some compact).
7. Iron bed (No. 2).
8. Alternating Quartzo-hornblendic and Hornblendic beds.
9. Iron bed (No. 4) see below.
10. Quartzo-hornblendic beds, full of large garnets, and of great thickness, forming the summit ridge.

The concentric appearance of the various beds as seen in plan is due to their forming part of an elliptical basin, owing its origin to a modified synclinal fold. The north side of this basin has been almost entirely removed by the gigantic denuding forces to which this part of the country has been subjected at some long by-gone periods.

The annexed sketch section across the summit ridge of Kunjamullay will explain the relative position of the beds, and of the synclinal axis showing its parallelism to the axis of the mountain ridge, and clearly illustrating the immense amount of denudation which has taken place. The relation of the whole mass to the rocks lying to the north, west, and south, has yet to be worked out, but the structure is due to a modification of a part of one of the great foldings of the gneiss-rock region.

A similar, but in some respects more perfect, example of an elevated basin formed by the denudation laterally of a synclinal fold, having its depression nearly in the axial-line of the ridge, is observable in Mulliakerra hill, in the Ahtoor Talûq. Here the ellipse is much less elongated, and its sides have not been so tremendously cut away; but the great iron beds are wanting, and consequently the curving of the beds is much less easily traceable.* The actual elevation of the whole mass is also greatly inferior to that of Kunjamullay.

Unfortunately, in both cases the surrounding country is much covered up by thick accumulations of soil, so that the relation of the rocks cannot be fully observed on all sides. It is, however, most distinctly to be seen in the one case at the north-east end of Kunjamullay, where the Chinna (little) Kunjamullay forms the diverging bed, and in the other case at the south-east end of Mulliakerra hill,† where the beds, (following them in an easterly direction,) instead of curving north-east towards the village of Chokalaveram, pass under the bund of a large tank, and re-appear, apparently, on the north face of Meckalupoor hill.

There are three principal beds of the magnetic iron ore, of whose continuity all through the basin there can be no doubt, although they are here and there covered up by debris; besides these, two others

* There is one small bed of rather poor iron ore on Mulliakerra hill, which might be very easily overlooked, as it is almost entirely covered up by debris from overlying hornblendic beds.

† Locally known as the Permalmullay; but there are several other hills bearing the same name in the Ahtoor Talûq.

appear on the summit ridge at the western extremity, but disappear in their easterly continuation under the debris and thick thorny jungle which there covers the upper and very steep parts of both slopes of the ridge, and greatly enhances the difficulty of examining them. If the various beds were numbered consecutively from below upwards, these would be respectively Nos. 3 and 5.

They may (very likely) be continuous all round the ellipse; but that fact could only be ascertained by very close examination, which would occupy many days, while practically they are of minor importance, as beds No. 1 and No. 2 would, from their more accessible position, first come under mining operations.

The two lower beds (Nos. 1 and 2) are exceedingly conspicuous, even when seen from a great distance, especially by morning and evening light, standing out along the flanks of the ridge, in generally well marked terraces (of dark purplish grey colour where not too much weathered), as shown in the accompanying sketch (Plate III*). We were unfortunate in weather when visiting the hill, and our sketch was taken on an unfavorable hazy morning.

The thickness of the two lowest beds (Nos. 1 and 2) varies somewhat, but the average will certainly not be much below 50 feet each, if not very considerably above this point; however, it is difficult to decide, owing to the very broken state of the beds near the surface, which renders it difficult to distinguish between blocks *in situ* and debris rolled down from the upper beds. The torrent sections do not afford much information on this point. The exact measurement, however, is of little importance, as, for all practical purposes, the supply may be considered as inexhaustible, even if only these two beds be taken into consideration.

Bed No. 4 is hardly more than 20 feet thick where best shown at the north-east end of the ridge.

Beds No. 3 and No. 5 are about equal in size, and but little inferior to Nos. 1 and 2. Vast quantities of the ore of these beds have rolled

R B Foote del^t

H J Fraser Lith

KUNJAMULLAY, from near railway station at SOORAMUNGLAM

down the mountain sides, especially to the southward, where, not only does the extensive talus consist mainly of it, but the fields, for 1 or 2 miles from the hill, are thickly strewed with it, in the shape of rolled fragments of all sizes. Thousands and thousands of tons are thus scattered about, and require merely to be gathered up without any mining operation.

In richness the beds are not constant throughout, but vary gradually from a rock, which to the eye would appear to consist of ore to the extent of seven parts in eight (the eighth part being quartz, the only mineral associated with the magnetic iron,) to one containing about half its bulk of ore; the great mass of the beds consisting of an intermediate quality, in which the cubical and octahedral forms of the crystals of magnetic iron can occasionally be traced. The ore generally occurs in grains of various sizes lying in the planes of foliation, and sometimes uniting into strings or into small laminar patches. The grains have, when freshly broken, a considerable metallic lustre; weathering, however, gives them a black, or very dull purplish-grey colour.

The yield in the furnace, according to information kindly furnished by Mr. Maylor, the Manager of the Porto Novo Company's establishment at Beypoor, is about 55 per cent. of iron pig,* requiring 13¼ tons of charcoal for every ton of iron obtained.

The iron beds of Kunjamullay are resorted to by the natives of the surrounding villages, both in the Salem and Razepoor talûqs, and their workings (of two kinds) may be seen in various places surrounding the foot of the mountain.

The kind almost universally adopted consists of small irregular shallow trenches or holes (rarely more than 3 or 4 feet deep) generally in the talus of the beds, but sometimes also on the weathered-out crop, from which the smallest and most friable pieces are collected and reduced

* Or about 62 per cent. of metallic iron of the finest quality.

to coarse sand by pounding (often with only a round stone) if not found in a state of sufficient comminution.*

The second method of getting the ore is by rude attempts at shafts, inclining according to the dip of the bed, and joined together by still more irregular galleries, all running in one line in the richest part of the bed; the greatest depth attained may be about 15 feet below the surface, and the greatest diameter of the shafts is certainly less than 6 feet. This second method of working, which, so far as could be ascertained, is confined to bed No. 1 of our list at the north-east end of the ridge, is hardly more effective than the first, yielding only a small quantity of the rough ore, and is dangerous, from the absence of any thing like timbering of the chambers. At this place No. 1 bed has of late been worked, chiefly by the first mode for the supply of the Porto Novo Company's works at Poolamputty, on the left bank of the Cauvery, 26 miles north of the great railway bridge at Errode.

The cost of collecting and picking the ore, Mr. Maylor states to be 1¼ Rupee (*2s. 6d.*) per ton, while the carriage to the works at Poolamputty, a distance of 20 or 25 miles, comes to about 3½ Rupees per ton, a heavy charge, which must considerably counteract the advantages of cheap fuel and water carriage during the flood season of the Cauvery, for which that site is said to have been chosen. It can hardly be doubted that the completion of the Railway will exercise great influence on the demand for the beautiful ore of Kunjamullay, and, it is hoped, greatly increase it.

The jungles of Salem district are being thinned, and in many places ruined, by the careless and wasteful way in which wood is cut down for building purposes; more still, perhaps, by the miserable native method of making charcoal; but the most wasteful and injurious practice, (and

* A full account of the process of smelting and of the various shapes of the smelting furnaces adopted by the natives, may be found in Mr. E. Balfour's Report on the iron ores, &c., in the Central Museum at Madras.

which is extensively adopted on some of the hill ranges,) is that of felling and burning down the forest in order to cultivate the freshly cleared piece of ground for a couple or at most three years, and then allowing it to return to forest growth, while a fresh piece of forest land is cleared, in its turn to be abandoned after a few crops have been raised on it. This is the so-called *ponakad* cultivation, and is the cause of the numerous conflagrations, often on an immense scale, which during the hot season may be seen in progress on the flanks and summits of the various mountains of this part of India.*

The smaller fires, kindled with the professed objects of improving the grass, are, in their way, also very injurious, by killing every sapling that the flames may encounter. That such is the case, any one may assure himself by taking the trouble to follow up the track of the fire.

That these practices have told and are daily telling more and more on the supply of wood generally, cannot be doubted, seeing that the price of charcoal has been almost doubled of late, and that timber of decent quality is with difficulty obtained.

It is owing, most likely, to the greatly increased price of charcoal that the number of native iron-smelting furnaces in Salem district has decreased in the last years, as shown by a return furnished by H. A. Brett, Esquire, the Collector. The natives in that district almost universally complain of great and serious diminution of the annual rain-fall, which certainly must be influenced by the wholesale destruction of the forests; while, from their great extent, and the numerous passes affording exit into the low country, the Forest Conservancy Department have as yet had but little power in materially diminishing the evil.

It is certain that unless much greater facilities for obtaining fuel can be given, the ore of Kunjamullay and the other places in the vicinity

* It is supposed by many that such a fire sweeps past the larger trees without doing them any harm; but such is practically not the case, as the heat given out by a burning thicket of brushwood or bamboo clamps, is enough to scorch and blast the largest trees, and burn off all the smaller branches and twigs.

can be utilized only on a small scale; the limestone near Sunkegherry Droog, where several beds cross the line of railway, would afford an excellent flux, easily and cheaply procured, and both the railway and the river Cauvery would afford ready means of transport for the produce. But the want of fuel is the great difficulty. Coal, even from the nearest point, Bengal, would cost, for carriage alone from Calcutta to Madras, from 25 to 30 shillings per ton (12½ to 15 Rupees), and this coal would be of inferior quality; charges which appear prohibitive of its use.

O. T. Cutter, Military Orphan Press,—1864.

4/-

MEMOIRS

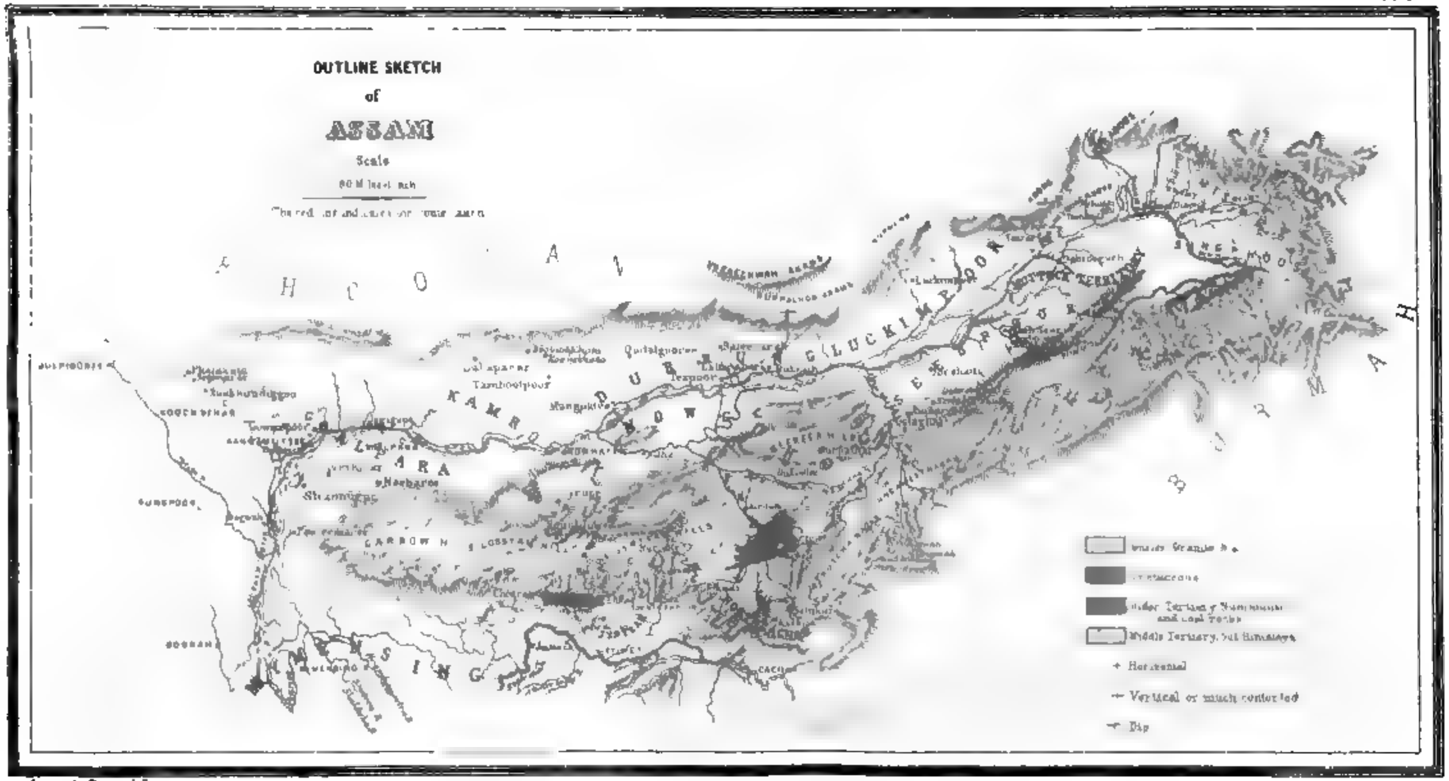
OF THE

GEOLOGICAL SURVEY

OF

INDIA.

Medlicott, H. B. *On the* Coal of Assam, *with* Geological Notes *on the adjoining Districts to the South.*


OUTLINE SKETCH
of
ASSAM
Scale
LUCKIMPOOR
Tezpoor
Tamboolpoor
Middle Tertiary, Sub Himalaya
Horizontal
Vertical or much contorted
Dip

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

The COAL *of* ASSAM; *results of a brief visit to the* COAL-FIELDS *of that Province in* 1865; *with* GEOLOGICAL NOTES *on* ASSAM *and the hills to the south of it, by* H. B. MEDLICOTT, A. B., F. G. S., *Deputy Superintendent, Geological Survey of India.*

THE object of my deputation to Assam—to examine the various coal-fields of the province—has, I hope, been accomplished as fully as could be expected in one season's work; and considering the unforeseen delays and difficulties which still further curtailed the time. The Steamer *Progress* in which I had taken my passage was wrecked in the cyclone on her voyage to Kooshtea; and the departure of other steamers was so delayed by the same cause that I could not leave Calcutta for a full month later than I had intended. The journey to Dibroogurh, moreover, occupied the unusually long period of thirty days, so that I did not get to work before the middle of December. The difficulties of the undertaking only then commenced, and they are not so easily accounted for. It is not the familiar obstacles of miry rivers and of jungles that I would mention; every one knows that these are prevalent in Assam; but the more than passive obstructiveness of the native population. Every European traveller in India must encounter more or less of indigenous apathy; but in no part of India have I found this very natural propensity so prevalent as in Assam, or so little under the control of the

Authorities. It seems, in fact, that law has set authority at naught. It is not for me, nor would this be the place, to give an opinion how far such a state of affairs is congenial to the prosperity of the country under existing political conditions; I allude to it in order that I may give due credit to Captain Comber, Deputy Commissioner of Luckimpore, and to Captain Lamb, Deputy Commissioner of Durrung, for such aid as they succeeded in giving me while working in their districts, at no small risk of being prosecuted in their own Courts. My entire means of carriage for the greater part of my stay in the Assam Valley was supplied by the Assam Tea Company; without the assistance thus so generously afforded, the extent of my explorations must have been very much curtailed.

The basis of my operations was given to me by the Commissioner in a Memorandum of information, containing a notice from each district of localities in which coal was known or supposed to exist. A copy of this document is appended.*

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* *Notes on the occurrence of Coal in the Districts of Assam.*

Captain Comber reports as follows :—

Luckimpore. "I cannot find in the records of my Office any notice of coal "being discovered elsewhere than in the vicinity of Makoom.

"My not having yet been able to visit that part of the district renders it difficult "for me to give much information on the subject. Coal was discovered some years ago on "the Terap River, and other spots in the vicinity of Makoom, and I would refer you to "the hand sketch submitted with Lieutenant Lowis' letter No. 35 of 15th February, "showing the different spots he visited where coal had been found; in only one place, "however, has the coal been dug much, and that is the mine on the Terap River near "Makoom, nor can I find that any attempt has been made to push the discovery further, "more coal having been already found than means available to work it; but it is supposed "that the whole of the country lying between the Boree Deehing River on the north, the "Patkai range (our territorial boundary on the south), the Namsang River east, and the "Terap, or even beyond it, on the west, is one vast coal-field.

"I would propose that on the arrival of the Geologist, I should accompany him to the "spot where I might be able to aid him in his geological researches, by engaging such "of the Singphoes and Nagas as can afford information of the whereabouts of coal.

My attention was so entirely directed to the object of my mission that I could not attempt to give a connected sketch of the geology of the regions visited; any general observations I may have to record on this subject will be considered supplementary to the principal object of this report, the coal.

"The coal tract is hilly, and covered with dense forest-jungle almost entirely un-"inhabited, and it is hardly to be expected that labor for jungle cutting, &c., will be pro-"curable in sufficient quantity to enable the Survey Party to complete the survey of the "whole tract above alluded to this season; still a commencement might be made on those "spots whence coal has been brought to the surface, and the Geologist could then deter-"mine what is best to bè done.

"I do not despair of being able to get together a party of Nagas to aid the Survey "Party in jungle cutting, carriage, &c., but should like to be early informed of the date "on which the Surveyor is to commence his operations."

Lieutenant Sconce states:—

Seebsaugor. "I have made every enquiry regarding the coal-fields of "the district, and I cannot discover that there are any within "my jurisdiction.

"The Jaipoor coal is within the Luckimpore District.

"Coal is reported to be in several places within the Naga Hills, but in my "enquiries which arose out of your letter No. 1, dated 3rd May, answered in my letter "No. 282 of yesterday's date, I consider it would be injudicious for me, without the "Commissioner's knowledge, to cause any local investigations in order to obtain any in-"formation for Professor Oldham."

Mr. Raban, the Deputy Commissioner, reports thus:—

Nowgong. "In reply to my enquiries as to the occurrence of coal in this district, I have been "informed that pieces of coal have been occasionally brought "by the Meekirs from the interior of the hills, but that they "jealously keep the secret of the locality through fear of these hills being visited by "speculators in coal."

Lieutenant Andrew states:—

Durrung. "A coal mine has been discovered in the northern extremity of this district at the foot "of an uninhabited Dufla hill, bounded on the west by "Borgong River, east by inhabited Dufla hills, south by a "small rivulet, north by inhabited Dufla hills."

[redacted]

Gowalpara.

Of the localities mentioned in the list given by the Commissioner, it is only of those in the Gowalpara District that I have made no observations. It would have been impossible, under the circumstances, to include this region within the limits of my work. The omission is, however, of less consequence, as, from the position of those localities in the western extremity of the province, the occurrence of coal there is of comparatively little importance. The examination of them may perhaps await the regular geological survey of the whole hill-region south of the Bramahpootra, an undertaking of which there can be some prospect, now that the topographical survey is in hand. It may indeed be anticipated that the coal south-east of Singmaree occurs under the same disadvantages as to quantity and distribution that obtain in the coal of the Cossyah Hills, of which it is probably a representative, but on neither of these points can a positive opinion be given.

"Of its extent nothing is at present known, it lying in a wild and almost uninhabited "tract of country. A man is out now bringing in a sample of the coal, which will be "forwarded to you for inspection. On his arrival I hope to be able to give further parti-"culars.

"Report states that there are other mines lying to the north of where the coal is "now being brought from, but fear of the Duflas prevents any one from exploring "further in that direction."

Captain Lamb says :—

Kamroop.

"I am not personally acquainted with any places in this district where coal has been "discovered, and there is no correspondence in the Office from "which I can glean any information on the subject."

Captain Morton reports :—

Gowalpara.

"I believe that coal is to be found all over the range of hills occupied by the "Khassias and Garrows. Whilst engaged in the operations "connected with the suppression of the Jynteeah rebellion, "the Officers of the Field Force came upon several beds hitherto unknown.

"In the Maps of the district and to the south-by-east of Singmaree, several places "are marked by the Surveyor as 'coal found here.' On looking over the records of my

Cherra Poonjee.

As on my return from Assam I made a rapid visit to the Cossyah Hills, in order to note any connection between the rocks that have been described there and those I had seen in Assam, I had an opportunity of seeing one of the coal localities indicated by Major Bivar, and that had not been noticed in Mr. Oldham's brief sketch of the geology of the district in 1853. The

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" Office, I find that a Mr. Sweetland was engaged, at first on his own account, and " subsequently on account of Government, from the year 1842 to the year 1844, in working " a coal mine near Poottimarree in the Kurribarree District, and not far from the Kal " River. The coal he found was considered of a good description. Mr. Sweetland's services " were dispensed with, as his operations did not give satisfaction."

Cherra Poonjee.

Major Bivar submits a Tabular Statement in the subjoined form of the occurrence of coal in his district:—

Coal-Fields.

PROVINCE.	District.	Field.	Locality.	REMARKS.
ASSAM ...	Khosiah Hills ...	Chaila ..	1. Wolong or Byrung	Bed 1 to 3 feet; inferior.
			2. Chaila...	Ditto.
			3. Mowlong	Ditto.
			4. Mastuck	Bed 4½ feet.
		Cherra ..	1. On the left of the road entering Cantonments from Moosmai.	Bed 28 feet; coal of good quality.
			2. Facing Cantonments	Bed 2 feet.
			3. Opposite declivity	Bed 17 feet.
			4. Surrareem	Bed 12 feet.
			5. Lyrenehon	Ditto.
		Moflong ..	Mawbelakur, ¼ of a mile to the right of the road south-east of Moflong near the sources of the Kala Pani.	A newly discovered mine; bed not traced, but the coal appears plentiful and of good quality.
		Mowsenhram ..	2¼ miles south-west of Mowsenhram.	Bed not traced; coal said to be good.
		Khyrim ..	Tanjeenat, far from water carriage.	Ditto ditto.
	Jynteeah Hills .	Lakadong ..	The coal is found over a plateau which extends over one square mile.	Bed in places 5 feet, and in others 12 feet thick; coal good.
		Jowai ...	Thurmong, about 2 miles south-east of Jowai.	Bed not traced; coal said to be good.
		Sutoongah ...	Coal is found about 3 miles to south of the village of Sutoongah.	Ditto ditto.

coal at Mawbelakur confirms all that was then made known regarding these deposits. It is here, no doubt, of local importance; it will save nearly half the cost of carriage to the new station of Yeodo, and may supply that demand for many years to come.*

Kamroop.

It is probable that the statement of the non-existence of coal in Kamroop is final. There is reason to believe that all the hills in the southern and central parts of this district are of crystalline rocks; and, unless the reported discovery of coal in the northern hills by some Officer of the Dooar Field Force proves to be very different from what I found in Durrung, there is little to be expected in that direction.

Tezpoor.

The discovery, long since published, by Dr. Hooker, of rocks of the Indian Coal Measure period at the foot of the Sikhim Himalaya had at first given me considerable hopes of some useful coal-deposits on the north of the Bramahpootra Valley. This expectation was in a great degree banished by the information given me by Captain Godwin Austin, just as I was starting for Assam, that on the Bhootan Frontier he had observed the crystalline rocks at the very edge of the plains. Thus it seemed that the continuity which is generally so marked in the Himalayan sections could not be counted on here. My hopes were, however, again raised regarding the Tezpoor or Durrung coal on hearing from the Commissioner that a trial of twenty maunds of it had given the most encouraging results as to its value for a fuel. I regret to have to report the total failure of

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* As an instance of the inconsiderate criticism to which geologists are frequently subjected—it was remarked to me as extraordinary, that Mr. Oldham had not discovered this coal at Mawbelakur; now any one who intelligently reads the report in question must see, that it is only a sketch from observations made at intervals during the hot weather recess, and does not in any degree pretend to be exhaustive; and further, that the facts exhibited regarding the uncertain occurrence of this coal would render the search for it something like a wild goose chase.

these seemingly fair promises. I have not merely to give a qualified opinion on the value of this coal, but to affirm my disbelief in its very existence.

When at Dibroogurh I had, in anticipation of my visit to the Duphla Hills of Durrung, made a short trip to the Abor Hills, north of Dibroogurh, I there found, somewhat to my surprise after the information I had received from Captain Godwin Austin, a complete representation of the sections I was so familiar with in the north-western Himalaya, so far at least as the outermost fringe is concerned, which alone I was able to visit. The first range of hills have a considerable elevation, rising abruptly from the region of the *Bhabur.* They are formed of massive accumulations of soft, gray sandstone, exactly like the principal rock of the well known Sivaliks, with occasional partings of mottled clays, and passing upwards into great beds of conglomerate. The dip of the strata is constant to northwards, towards the main hills; the lowest beds thus showing at the outer base; and from the frequent occurrence of slips, forming bare cliffs on the south face of the hills, it is possible from a little distance to judge with considerable certainty of the extension of these rocks. Nests and strings of lignite are as common in this sandstone here as elsewhere, and it is these that have so frequently given rise to reports of the discovery of coal. The conditions in the Duphla Hills, north of Tezpoor, are exactly the same as I have just described. The Deputy Commissioner had been to this locality a few days before my visit, with the native who had supplied the twenty maunds of coal. When he expressed his surprise and annoyance at being shown these miserable pockets of lignite, he was told that the quantity supplied had been procured from a thick bed occurring some little distance up the river gorges; but these are only accessible with great difficulty, forming as they do a succession of deep pools between sheer cliffs of rock, and of rapids over great boulders; so Captain Lamb had to return, leaving orders that boats should be in readiness to take me to the mine. The natives, however, saved themselves this unnecessary trouble by confessing to me that the story of the thick bed was an invention, and that all the coal sent

had been picked up along the base of the hills at a great expenditure of time and labour. I have, moreover, a strong suspicion that the deception did not end there; that the man interested in the fraud substituted real coal for what may have been procured from the Duphla Hills. Had a specimen of this sample been kept, it would be easy to determine this point. I can scarcely believe that twenty maunds of this lignite *could* be procured, upon which any practical man would pass the opinion above stated: it is rare to get a piece of 3 inches cube of which a considerable portion does not consist of silicious petrifaction. The object of this roguery was to obtain an advance of money to work the supposed mine; in which, I believe, the man succeeded. Of course I should not have given up the search upon the mere fact of natives contradicting each other or themselves, but the rocks spoke plainly enough; it was certain that for several miles up those impracticable gorges I should find an ascending section of these Middle Tertiary strata, which all experience has hitherto shown to be barren of any useful mineral fuel. I cannot speak with any certainty of what may exist far up inside these Sub-Himalayan rocks; (Damuda) strata may be there, and with plenty of coal; but if so, it is certainly beyond the reach of profitable exploitation.

Nowgong.

The information from Nowgong is, I fear, of something the same kind as that from Tezpoor; it rests upon the report of one Meekir, given at second hand to the Deputy Commissioner, who informed me that this Meekir is well known about the Courts as a man of very doubtful veracity. As well as I can judge from the approximate position of his village, there seems even a direct probability against the occurrence of any kind of coal there.

Seebsaugor.

The question as to whether there is coal in the Seebsaugor District depends upon the temporarily doubtful point—what is the boundary of the Naga territory? or, is there such a thing as Naga territory? Some recent cases of dispute regarding grants of tea-land are likely to bring this question to an issue. It seems anomalous that in the extreme north-east the Patkai ridge should

be the acknowledged boundary between us and the Burmese, and that towards the south-west, in North Cachar, the Burrail ridge, which is the physical continuation of the Patkai, should be our boundary with Muneepoor, while intermediately, tribes of naked savages should be permitted to assert a mischievous independence. It is, moreover, only a recent pretension on their part, suggested by some years of immunity from control. I was informed by Major Holroyd, who has either personal recollection or the most direct information regarding the settlement of the North-East Frontier, that the Patkai range throughout its entire south-eastern extension was *then* understood as the limit of British territory; and that for some time the Nagas of those parts formally recognised the authority of the Civil Officers at Seebsaugor. A little judicious firmness would, I believe, easily re-establish the normal order of our relations with these people. Their present state of insubordination was a principal cause of my having seen so little of the important rocks forming the hills south of Seebsaugor. I will discuss the few observations I was able to make, in connection with those of the adjoining region in the Dibroogurh (or Luckimpore) District.

Luckimpoor.

In my notice of Tezpoor coal localities, I have described what I observed in the Abor Hills north of Dibroogurh. It is to be hoped that future explorers in these regions will keep in mind the views recorded, and will endeavour to discriminate between coal that is useful in quality and quantity and coal that cannot be so regarded. This is not the first time, though, I trust, it may be the last, that false hopes have been based upon the lignite sandstones of the Sub-Himalayan rocks. My observations of the coal to the south-east of Dibroogurh are discussed in the following paragraphs :—

Good coal in Upper Assam.

After so many reports of failure, it was pleasant to come to something worthy of every attention. It is pretty generally known that coal exists over a large extent of country in Upper Assam; that it has for several years been worked; and

that, of some at least, the quality is unexceptionable. It only remains for me to give a professional opinion upon the extent and placement of these deposits. On both points my opinion is, on the whole, favorable. This opinion is based entirely on direct evidence, independently of any more remote geological consideration of the period to which the deposits belong. From this latter point of view, indeed, the argument of analogy would be adverse: I have, unfortunately, not been able to obtain the conclusive evidence of fossils as to the age of these coal measures; but the best opinion I can form from the comparison of the sections is in favor of the coal belonging to the Nummulitic period, the same which hitherto in India, as in the Cossyah Hills, the Salt range, and in Scinde, has more or less disappointed our expectations of an extensively useful coal-formation.

Two fields; their positions.

There are two places prominently known in Upper Assam as coal-producing; one is the neighbourhood of Jaipoor in the Seebsaugor District, and the other is in the vicinity of Makoom. In the latter the diggings of the Terap are much the most extensive, and the only ones now worked. If, as I think is the case, the coal beds in both localities belong to one and the same group of rocks, it is probable that they are confluent somewhere in the hills south of Jaipoor, and that thus the two localities would be but portions of the same great coal-bearing region. At present, however, we must treat them as distinct. The Jaipoor localities are in more or less continuous connection with those known to occur in the outer zone of the hills to the south-west, up to and beyond the Dikhoo, and even, I believe, to the Dunseeree. If, indeed, my conjecture as to the age of this coal is correct, we may expect the connection to be traced into the Jynteeah and Cossyah Hills; but, as in such a position it might be regarded as valueless, this question may be reserved for purely geological consideration. In a north-eastern direction the band of rocks, which along the Seebsaugor District forms the outer zone of the Naga hill-group, strikes across the Deehing at Jaipoor to form the long spur, called the Tippum range, which

gradually dies out in the plains south of Suddya. The Terap coal region lies on the flank of the main hills to the south of this little range, from which it is separated by the valley of the Upper Deehing.

Geographical advantages of the Jaipoor field.

There is thus at the outset a manifestly great advantage in favor of the Jaipoor localities and others in the same zone; direct and level roads can be run almost to the pit's mouth; in the rains, boats of the largest size and even steamers can come into the immediate vicinity, and boats of moderate burden can do so throughout the greater part of the year. The Terap field is much further from a market; unless from Suddya no direct road could be made to it without crossing the Tippum range; the only water carriage to it is by the Deehing, and this river above Jaipoor passes through a course of rocky banks and strong rapids impassable for steamers or the larger class of native boats. It is, however, fortunate that this valuable coal-field is not quite cut off from this cheapest mode of carriage; the Mohurrir at the Terap mines told me that boats of 300 maunds' burden can make two trips during the flood season to and from the Dikhoo Mookh.

Superiority of the Terap field as at present known.

At present, however, the great superiority of the coal from the Terap over that extracted at Jaipoor more than outweighs the geographical advantage of the latter field. All the coal brought to the Bramahpootra for steam purposes is from the Terap. The Jaipoor coal is used almost exclusively for such purposes as brick and lime burning. A more positive fact of general importance is, that the Terap coal is now delivered at all the stations of Upper Assam at a much cheaper rate than coal brought from Bengal, the latter being probably reduced to a minimum cost, while the former is as yet worked under every disadvantage, at a premium rate, by a thriftless native contractor, under abnormal conditions of the labor-market. We may then come to the consideration of the intrinsic conditions of the Terap coal-field. I give it precedence, because it must as yet be looked upon as *the* coal-field of Assam; and a

chief argument I have to put forward why it may not remain so involves a double probability—the identity of the Jaipoor rocks, and the uncertain (however presumable) permanence of development.

The Terap Section.

The condition of the seam worked near the Terap is somewhat singular. All the coal hitherto removed has been from a bed in a nearly horizontal position, and covered only by superficial deposits. The quarry presents an east face, more than 20 yards long, showing at the base a minimum thickness of 5 feet of clear bright coal; the top of this is an irregular denudation surface, remnants of the overlying shale being here and there seen. Over all there is about 10 feet of stiff yellow clay, in which, sometimes resting on the coal, are some very large subangular blocks of the sandstones which form the ridge immediately to the south. The perfectly undeteriorated condition of the coal in contact with the clay is remarkable; but indeed, under the shelter of the dense forests in these regions, bare outcrops are found in the same state. There is still to the westward much coal in about the same condition as that described. At a few yards north of the quarry a low northerly dip takes the coal under ground; and immediately to the south it passes into the base of the abrupt ridge, with a decided southerly dip. Unless in fresh artificial cuttings, good rock sections are very rare in Assam; the indications I obtained on the steep hill-side above the coal-quarry are, however, sufficient to satisfy me that the coal at the base is no isolated occurrence. For at least 200 feet shaly carbonaceous clays form a large element of the section, and among them I noticed at least two beds of good looking coal; sandstones succeed, forming all the upper part of the ridge. Throughout all the southerly dip is maintained. This circumstance of placement gives a special value to the Terap locality; for, as far as I have seen, the general condition of these rocks is one of great disturbance. It would be a very light work to clear a complete section of these rocks on the hill side, an operation which would naturally be the first to suggest itself to any one undertaking to work the coal.

The Namchik Section.

The only other important section I obtained of these rocks was at the Namchik. This is, like the Terap, a tributary of the Deehing; it is three days' journey to eastwards, up a constantly diminishing stream, though scarcely twenty miles in a direct line. The outer hills are here lower and less steep. The best section I obtained was in a small stream flowing northward, shortly before the ridge is interrupted by the gorge of the Namchik. Within a length of about 200 feet, including several yards of covered ground, I noted three thick beds of sound, good coal; one of them, eight feet thick, has the unusual crystalloid structure which seems to characterise the seam now worked on the Terap. Fine shaly carbonaceous clays are freely associated with the coal beds, the rest of the section being occupied by sandstones of the same kind as accompany the coal at the Terap. Throughout this section the strata have a steady dip of about 65° to south-south-east. At about three miles to westwards the same rocks have a high dip to south-30°-west; thus even the strike of the strata is subject to much local variation.

Inferences.

There cannot, I conceive, be any reasonable doubt that the sections of the Terap and the Namchik belong to the same band. Considering the character of the rocks, the steadiness and the uniformity of individual beds, and the strong general uniformity of the group at two such distant places, it would seem that these deposits offer a nearer approach to the type of regular coal-measures than any yet known in India. If the coal seams noticed by me were the only ones in the field, which, I need hardly say, is extremely improbable, the supply they promise is practically unlimited. But they extend to an unknown distance eastwards; and to the westwards they have been traced, and even worked, in several localities. The extension of them is, as I have already observed, to be sought in the hills south of Jaipoor; here, however, they would for the most part be out of reach of profitable extraction.

The presence of coal in the earth is, however, only the first requisite.

Conditions of placement.

For its profitable extraction there are other very important conditions to be considered. In the Terap field these are by no means altogether favorable. I have always found these rocks inclined at very high angles, except at the Terap itself; and even concerning the apparently little disturbance here, I will presently suggest some serious doubts. Besides the high dip, I have noticed frequent local variations in the strike of the strata. These irregularities would involve expenses and complications in any extensive mining operations, showing beforehand the special necessity of commencing any such enterprise under skilful (scientific) management. It is no doubt a great advantage for the transport that the measures should crop out at the very edge of the level country. But where this feature is at its best, coupled with a high underlie of the seam, drainage becomes a serious difficulty from the very outset, specially in such a watery country as Assam. Such, for instance, is the condition of the coal band in the vicinity of the Makoom and the Namding Rivers. At the Namchik and the Terap there must be a large quantity of coal above the water level of the adjoining plain. It is to be presumed that other localities are to be found in equally favorable circumstances.

The Jaipoor field.

The only sections I was able to obtain of the Jaipoor coal band were very obscure. The principal quarry worked is close to the left bank of the Dehing; in it the individual bed is pretty well seen. This seam crops out at the very foot of the steep scarp, about 100 feet above the water level. It is overlaid by the sandstone of the scarp, and slightly blended with it by interlamination, showing original association. The dip is very high and there is much crushing. The seam is about 17 feet thick, of which about 10 feet seems good clear coal; but owing to the crushed state it becomes irregularly mixed, and careful cutting would be necessary to get it out in block. About a quarter of a mile to the south-west there is

an abandoned quarry. It is not on the same seam, being capped by shaly carbonaceous clay; and the scarp does not rise for some yards behind it: the nature or condition of the seam is not now traceable. On the right bank of the Desang, under Borehaut, I got a tolerably continuous view of the band. The section is oblique to the strike and low, the hills being here cut back in the bay of the gorge. The dip is high, and variable in amount and direction, there being also much crushing. On a length of about 100 yards, which may not include the whole band, there seem to be nine coal outcrops, four of which are apparently thick and of fair quality. The associated rocks are principally shaly carbonaceous clays, with sandstones. There is evidently in this section independently of any identification with the Terap coal-measures, ample encouragement for the further exploration of the Jaipoor field. Several seams exist that have never been touched. The one at Jaipoor seems to be the topmost of the group, and is not likely to be a favorable sample of the whole; it even has not been fairly tried; in other positions, or when properly worked, it may prove of excellent quality; and as the highest bed in the field, it will always, under the conditions of the section, present greater facilities for working. But better seams may with much confidence be expected below it, especially on the supposition of the identity of the two fields. The general placement is the same as in the eastern field, along the base of the range, towards which the beds dip at a high angle; and the simplest mode of exploring would be the same for both—to seek some point where the coal-bearing band reaches as high as possible on the ridge, probably where the range is most prominent, and to make a cut across the strike.*

Geological identity of the measures probable.

* The question of the geological identity of these two coal-rocks involves some considerations affecting the estimate to be formed of the prospects in each. The confirmation of this identity would certainly be most encouraging to success in the Jaipoor region. I have not *seen* any thing in this field so promising as what is well seen in the Terap and Namchik sections. On the other hand, this identification would entail serious

The point on which my season's work is most deficient is in the examination of the important region south-west from Jaipoor, where, no doubt, the coal band is continued. Without official assistance, it would not have been safe or

Further extension of the Jaipoor field.

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complications in the placement of the rocks of the latter region, the apparent sequence being reversed and that of the Jaipoor section being normal. It will not be easy to make this matter intelligible to those who are not geological, but it is clearly part of the practical question before us and must be attempted here. The general similarity of the coal-bearing band in the two regions is quite sufficient to afford a *primâ facie* probability of their identity, occurring, as they do, in such proximity and under physical conditions so much alike. The coal seam at Jaipoor is, as I have said, *associated* with the sandstone which overlies it. This sandstone is of marked Sub-Himalayan type (I use this term with the more confidence as these rocks occur in every sense so characteristically on the north of the valley), and is seen in the gorges of the Desang and of the Dehing to pass upward through a great thickness of the same rock into such strata as usually terminate that series,—clays, and coarse conglomerates. This must be a normal section, fixing approximately the Jaipoor coal in the nummulitic horizon. In the Terap and Namchik sections the sandstone alternating with the coal, and overlying it in considerable thickness, is persistently of a markedly different kind from that at Jaipoor. The alternative conclusions thus suggested are:—that the groups are different; or, that a very considerable difference of condition affected the formation in the two regions; or, that in the eastern sections the rocks are inverted. This last supposition, which is the one I am inclined to favor, also requires the suppression of a portion of the coal-rocks in each section: I did not recognise the sandstone of the Terap measures *at all* in the Jaipoor section; but the base of this section is not exposed: the coal seam at the Terap is the lowest (or highest) bed seen; but it certainly is not at either limit of the coal band: in the Namchik section, the supposition of partial suppression is also tenable; and here we do find, although the section is broken, strata of unmistakable Sub-Himalayan type in apparent *underlying* sequence to the coal band. Thus it is seen that the supposition of inversion is not gratuitous. There is, indeed, nothing in the nature of the rocks seen in the Namchik sections, which need *independently* involve the reversion of the apparent order; but the normal ascending sequence of these Sub-Himalayan rocks is so well established, even, I may say, in this neighbourhood, that the supposition becomes imperative of their being younger than the rocks which here apparently overlie them. Still, inversion would not be a necessity; there might be a fault, or a compressed natural boundary between them,

possible to march along through the hills; and the Seebsaugor authorities, to whom these hills naturally belong, had disclaimed the right or the power to aid the undertaking. When I was at Jaipoor I had no elephants to attempt the route along the base of the hills; I was, moreover, told that it was almost impracticable,—my trip to the Namchik and through the Singphoo District was effected entirely by canoe in company with Captain Comber. I consoled myself with the prospect of taking up the Seebsaugor hills again in the neighbourhood of Nazeerah. This I did; but circumstances proved unfavorable, so that my observations were far less satisfactory than could be desired. There can be little doubt that for some distance beyond the Desang to the south-west, the same conditions obtain as I have noticed between that river and the Dehing; and it is not unlikely that local circumstances may be found more favorable than any in the Jaipoor neighbourhood; the outcrop may reach higher on the range, affording a good section of the band. A similar inference may be made regarding the continuation to the north-east along the Tippum range; but very little is to be expected here. I visited the *púng** near Bazalani, eight miles beyond the Dehing; I believe it to be on the outcrop of the

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each being in its original vertical order. Besides this general argument there are some local facts to favor inversion. On the Makoom River, about 10 miles west of the Terap, Sub-Himalayan sandstone occurs to the south of the coal, dipping from it, and thus apparently overlying it. Supposing the coal the same (it is very badly seen), both these sections cannot be normal. This locality is, as I have said, at some distance from the ridge. I suppose it to be on the north of the axis of flexure. The other observation to which I allude is the position of the gas and petroleum springs at the Namchik. There are several of these *pungs*; the most numerous and copious occur, in their natural position, about the outcrop of the coal band; those, however, that have been stockaded for elephant-catching rise through the clays and sandstones of the Sub-Himalayan rocks, suggesting that under these too the coal occurs. The chief difficulty to the supposition of inversion—I may say the only one, for such phenomena are by no means very rare—is the seemingly little disturbed state of the rocks in the Terap section; there is even a small flat anticlinal close to where I want to introduce a main synclinal flexure.

* See below.

coal; but it is quite at the base of the range. It is probable that the band soon becomes altogether depressed.

Region of the Dikhoo.

The low hills about Cheryedo, east of Nazeerah, are, as usual, so deeply coated with soil derived from the decomposition of the subjacent rocks, that nothing I can call a section is obtainable. From the evidence of the occasional debris I infer them to be of Sub-Himalayan rocks. It may be worth notice that on Dolbugán, the most north-westerly of these hills, this debris *in-situ* resembled the Terap sandstone rather than that of the younger series. At the entrance of the gorge of the Dikhoo, and for some way up, there are good sections of the massive, clear, gray, sandstone and mottled clays of Sivalik type, having a high dip to east 30° south. This strike would about take them into the hills of Cheryedo. I conjecture that the coal marked on some of the maps close to this may be only the lignite, which is as much scattered through these rocks on the south as on the north of the Bramahpootra Valley. The coal I was taken to see is some miles in, near the crest of one of the higher ridges, a short way north of the Naga village of Kangan. It was formerly worked, I believe, by the Assam Tea Company. The position of this pit is quite enough to account for its being abandoned. The workings have fallen in, and the outcrop is completely covered, so that I could see nothing of it. I noticed, however, that the sandstone which is freely exposed at many places on the ridge, is all like the rock of the Terap; only coarser, being often sub-conglomeritic. I could see nothing of earthy rocks. Both these symptoms are indications of original diminution of the coal-measures in this direction. I would scarcely think of noticing such isolated observations were it not that they concur with the general features of the whole hill region. Between the Dikhoo and Gabaroo, the low hills seem to be entirely formed of the Sub-Himalayan rocks. Near Deopani I was taken by a planter to see a "coal bed;" we could, however, only find nests of lignite. But it should not be forgotten that the coal is contiguous to these rocks, and

may therefore be sought for in the same region. The enormous thickness of the younger series is the great obstacle to the search; it is impossible to know with any precision how near or how far we may be from the base.

Region of the Dunseeree.

In the region of the Dunseeree I have no observation of the ground from which any thing may be expected—the hills of the Angami Nagas. It seems probable, from the considerable suppression of the lower flanking hills to the south-west of Gabaroo, that the coal-bearing band may there be brought within reach of the plains. Close to the left bank of the Dunseeree, at the Namba Falls, about 10 miles above Golaghat, crystalline rocks appear; and close to them is an undisturbed remnant of sedimentary rocks, which I conjecture to be of an older period than the coal-measures. All the hills to the west of the Dunseeree below Golaghat are of crystalline rocks.

Region of the Kopili.

All the hills below Kerania on the Kopili are of crystalline or schistose rocks. At the Falls there is a section remarkably like that at the Falls of the Namba: a small rib of gneissose rocks partially covered by sandstones. The probable position of the coal band on this section is well out of reach of Assam.

It may be affirmed with great probability that all the rocks on the south of the Assam Valley, west of the Dunseeree, are crystalline rocks.

Quality of the coals.

It has been already stated that the excellent quality of these Assam coals has been placed beyond a question by years of experience; results to which analysis gives complete confirmation. The following quantities were determined by Mr. A. Tween for three samples of coal brought by me from Assam :—

	Fixed Carbon.	Volatile matter.	Ash.
Terap	61·8	36·5	1·7
Namchik	50·4	44·6	5·0
Jaipoor	53·0	43·3	3·7

The first is an average sample of the coal now quarried at the Terap, taken from a heap ready for shipment. The second was taken from the

very surface of a natural outcrop in the bed of a stream; the bed was not that noticed as identifiable with the Terap seam. The third I cut myself in the Jaipoor quarry. These figures show clearly the value of these fuels. The proportion of ash is remarkably low, even compared with that of English coals. In these analyses the inferiority of the Jaipoor coal is not apparent. It had, however, fallen to fragments in transit, the others remaining whole. The two first cake; the Jaipoor is free-burning; for many purposes this is advantageous. Still the proportion of volatile matter in all is somewhat in excess of that contained in coals best adapted for the general purposes of manufacture and commerce.

Small use hitherto made of the coal.

It will seem strange to those unacquainted with India and with Assam that up to this date the valuable coal deposits of Upper Assam have lain useless so far as concerns the general industry of the province. For many years the Bramahpootra has been regularly navigated by steamers as far as Dibroogurh. The whole trade of the province is dependant on these steamers, unless in the case of the more wealthy settlers, who can keep up a transport establishment for their own use. A local carrying trade does not exist; one may steam for days on the Bramahpootra without meeting any craft above the rank of a dug-out. There are no main cart roads, even between the principal stations. For a voyage, of which the upward course reaches to thirty days, it may be imagined what must be the difficulty and cost of carrying coals from the starting point. I was told that coal so brought to Dibroogurh must be valued at two or two and a half Rupees per maund. Wood, of course, exists in endless profusion on the very banks, but the cost of cutting and stacking it, even when it is possible to procure the labour, bring it to nearly the same relative value as imported coal. Yet for some years it

Its present cost.

has been an established fact that first-rate coal can with profit be delivered on the Bramahpootra for fourteen annas per maund. This is the contract price of the coal from the Terap, stored at the Dikhoo Mookh for the use of the Govern-

ment steamers, for which alone the source seems to be available. At present rates it appears that coals from below and from above would interfere at about Tezpoor: it is stated in an official letter by the Commander of the Government Steamer *Koel*, that coals shipped at Kooshtea for nine annas per maund can be delivered at Gowhatty for 11¼ annas.*

Causes for the neglect.

Several causes must contribute to create circumstances so anomalous. Foremost there is no doubt the depopulated, uncivilized state of the country; where, to undertake any branch of industry, one must provide every thing connected with the production, however remotely. There may, perhaps, also be a doubt, whether the demand for coal has hitherto been sufficient to remunerate for any extensive operations of extraction; it is, however, considerable; and it may confidently be expected rapidly to attain a large extension; a supply of coal would in itself greatly encourage this extension. For an indefinite period, the trade of Assam must be carried on by the Bramahpootra; and steam-power is likely to keep the supremacy it has established; prospectively it is almost matter for congratulation that this noble stream is free from the lumbering native boats which swarm on the rivers of Bengal. The all-absorbing nature of tea-cultivation partly accounts for the neglect of the coal; and this fact says much for the profits of that trade. It is impossible, however, not to regret that some more energetic endeavour to open out so important a field of industry had not been made by the Government. We believe the present investigation was suggested by applications for the purchase or lease of coal grants; and yet all arrangements for such grants are still in abeyance. The difficulty of making these arrangements with due regard to the interest of all parties concerned is not slight, under the peculiar circumstances of the country. The field is, indeed, large enough for many workers; but will these be forthcoming? There would

* I cannot say what elements this estimate includes or excludes. I doubt its being taken from the carrier's point of view.

be great risk of a monopoly arising; and this would leave matters scarcely better than before—it is highly improbable that for many years to come coals would be sold at the Dikhoo Mookh at fourteen annas per maund. At the same time it is essential to be liberal, and not to hamper the grantees with any arbitrary conditions that can be avoided. Some sacrifice and inconvenience are inseparable from new undertakings.

Conditions attached to coal property.

The terms already proposed by Government in the case of these mines cannot be objected to, namely, six annas per acre, and one rupee per hundred maunds of outturn. Under the peculiar circumstances—the surrender of a natural resource, so largely affecting the interests of all, to one or few parties, as would probably be the result for some time to come—it would seem desirable and reasonable to superadd, to the usual demand of proved competence on the part of an applicant to work the mines efficiently, some more positive engagement; or at least to take every possible precaution to ensure fair treatment to the public. I think this might be effected, without the objectionable measure of fixing an arbitrary minimum to the out-turn in quantity or in price, by leaving these considerations as voluntary items of the bargain on the part of the applicants, to be trusted to their sense of integrity and of self-interest. Efficient checks can, I think, be ensured to the Government as depositary for the public. With this in view, I would object to the plan proposed to selling mining grants without reserve by public auction. I would rather let the competition take the form of tenders, leaving the absolute election to the judgment of a committee of competent Officers. This would also avoid the waste of the capital sunk in purchase-money. But the most important check is the due limitation of the grants; by this, and by preventing the obtaining of grants by indiscriminate and mischievous competition, it would probably be in the power of Government at any time to exercise a prudent control over the supply: either to bring legitimate pressure to bear upon illiberal mining-proprietors, or,

on the other hand, to protect in some measure the public, the coal-fields, and proprietors who may do justice to both, from rash and invidious speculation.

Settlement of grants.

The difficulty in fixing the grants has been a main cause of delay in opening up these coal-fields, and it certainly deserves every attention. It was proposed by the Commissioner that I should, in co-operation with an Officer of the Revenue Survey, attempt some such settlement of areas; but the suggestion was manifestly made without due consideration of the work, in a forest-covered country, where the first elements of a map had yet to be fixed, and where every thing had to be learned regarding the rocks. This undertaking would, moreover, have been incompatible with the object of my mission to Assam—to form a general opinion of the coal-resources of the province. The objects to be held in view in assigning grants are—1st, that, as far as possible, each grant should be so limited that the deposits within its area may be fully worked from a single mine; this area might be looked upon as a normal or integer grant: 2nd, that within each grant there shall be ample scope for the full development of an extensive mining concern. This latter condition is evidently contingent upon the productiveness of the Measures; so that to be fulfilled it might be necessary that a *concession* should consist of more than one unit-grant. There are, of course, in every single case, special circumstances of position and of physical features to be taken into account, so that, even supposing the constants to be ascertained, it is *primâ facie* objectionable to assign any one fixed area as the limit for a grant. In countries where these matters are properly administered, these arrangements, as well as a certain supervision of the mining operations, are primarily confided to the mining engineers of Government. It were to be regretted that objects so important should be lost sight of in the present case; yet it cannot for a moment be contemplated to withhold the rights of mining until such

arrangements can be made. The circumstances of the case admit, I think, of a temporary settlement of all difficulties. Owing to the placement of the rocks in Assam, the difficulty of fixing the area can be for the time eliminated. In many coal districts, where the deposits occur more or less approximately parallel with the surface, and the underground works can be connected almost without limit from the surface, the element of superficial area is all important. In every case, I observed in Assam, the measures are so placed, either having a very high underlie, or situated at the base of a steep and lofty ridge, that all the coal to be extracted from any given length of seam must be got by one pit, at or near the outcrop. Thus it becomes easy to assign limits to what should be considered *a mine*; and I would recommend its being done, with a view to discourage the dependance of proprietors upon mere open workings along the outcrop—a thriftless method not unlikely to be adopted if there were vague rights admitted over a large area, or if grants were obtainable indiscriminately on demand by the highest bidder; but a method most mischievous to the future prospects of the coal-field. It is also essential that each grant should include the whole thickness of the measures, all the seams of which could be worked to the best advantage by one mine under one management. We thus have two approximately parallel lines and a fixed point between them upon which to base our provisional definition of *a grant*. There is a further important natural limit, to which I have already alluded; such a grant here may be considered an ample *concession*—it is certain that all the coal seams within the length of a grant in the Makoom coal-field would give full occupation to the most active enterprise that the case at present admits of. I believe, further, that the whole actual demand for coal in Assam could be most economically supplied from a single concern so conducted. If my views are correct, no straightforward, honest, and intelligent adventurer could demand further opportunity for applying his capital. Finally, then, I would suggest as a provisional defini-

tion of a grant, that may be immediately put in force,—One thousand yards of the coal measures; the terminal boundaries to be a line at right angles to the strike of the rocks at each end of the length; the central point to be chosen by the applicant. To admit of the disposal of several grants, while avoiding the collision between grantees, and pending the settlement of natural boundaries by competent judges, it would be well to rule that a new applicant must not come within one mile of an actual holding. It is unnecessary that this interval should be an exact multiple of the provisional arbitrary length of a grant; for when the final arrangements can be made, the interests of *all parties* will lead to a considerable modification of the temporary length, leaving grants both much over and under the assumed standard. The present object is to give immediate opportunity for the opening up of the coal-field with due security to the enterprise and protection to the resources of the country. All these elements are easily measured and verified, and leave little opening for dispute: they may be adhered to for many years to come without doing prejudice to the development of coal-fields so extensive as these. As an encouragement to the enterprise, and as a spur to Government to have proper final measures carried out, I would recommend that the land-rent of the grants be remitted until final boundaries are fixed and the area measured.

Labour.

The want of labour, which presents such great difficulty to every undertaking in Assam, must, of course, affect the working of the coal; but, as it would seem, in a less degree than it does tea-cultivation. The Nagas, who can rarely be induced to accept work in the tea gardens, appear to have less objection to the much more severe labour of cutting and carrying coal; it may be because the locality is within easy reach of their villages on the hills. Such, at least, has been the experience in the small workings hitherto carried on; but this source could scarcely be exclusively depended on. It is, however, most important that this supply should be encouraged in

every way; and on this account alone it would be most desirable that some change should be speedily made in the present system of working the coal deposits. The native contractor, whose interest in the mines is of the most temporary nature, seems to pay little attention to this important matter; there were numerous complaints at the Terap of the labourers being constantly in arrears of pay.

Mineral resources.

Assam has not escaped the usual fate of newly opened regions, of having its "mineral resources" spoken of in the most extravagant and unfounded manner; it may, therefore, be expected that I should offer some remarks on the same subject. With the exception of coal, of which the province seems to have a fair share, its mineral resources, as far as I can judge, approximate to a minimum. Even some of the commonest substances of extensive and necessary demand are unusually deficient. The whole of Upper and Middle Assam is supplied with lime from stones picked up in the beds of torrents north-east of Suddya, at a distance, in many cases, of several hundred miles. Such a source is necessarily limited, the process of boulder production and distribution being slow, and would soon perceptibly decrease if the demand were at all active; but the inhabitants, settlers included, for the most part content themselves with buildings of wood or of mud, and the public works are as yet imperceptible. If the coal-measures are of the age I suppose them to be, it is to be regretted that the limestone, which accompanies them in the Cossyah Hills, should not continue; but even there its presence is capricious; if it has any representative in Assam, it must be very subordinate. The only symptom of limestone I obtained in this position was one small piece (of a light gray, veined variety) in the Makoom River; I could not say whence it came. I was surprised to see that no use seems to be made of the bed of limestone at the Namba Falls; its existence has long since been made known by that indefatigable explorer and collector, Mr. Masters, of Golaghat. The free stones of

Lime.

the sedimentary rocks in the hills bordering the valley are not likely to be in demand during the present generation, and still less the strong granite of Tezpoor and elsewhere.

Iron.

A good iron ore in a propitious place would be of incalculable value to Assam. I regret that I can suggest no prospect of such a discovery. I looked closely for iron-stones among the shales of the coal-measures, but detected none. Ferruginous symptoms are not wanting. The outcrops are sometimes crusted, and more or less penetrated, with irregular shells of iron oxyde; it is sometimes even abundant enough to supply a native forge, though I do not know of its having been used. It seemed to me, however, to be all due to superficial concentration. There is no doubt iron disseminated in these shales: but a very moderate quantity, even that contained in the form of pyrites, would by concentration and accumulation at the surface produce the observed appearance,—it is a common effect of the disintegration of rocks by atmospheric action. There seems to be a general notion that any rustiness about soil or rock must indicate a useful iron ore. One very fatal symptom may be noticed on this subject: at several places along the foot of the hills, I saw Assamese smiths at work making weapons and implements for the Nagas out of English iron.*

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The occurrence of gold in Assam seems to be a very general subject of interest to the residents. It is, however, quite in abeyance to tea-cultivation; the pursuit of it may safely be left to those who have nothing better to do. The precious metal does not seem to be more abundant than in several other parts of

* The blowing apparatus used by these men is the most advanced I have yet seen in native hands in India; it is probably borrowed from Burmah; one double-acting cylinder, very simply contrived and well put together; the piston rod is worked horizontally by hand; the only defect in principle is the want of external valves in the blast-pipes, the nozzles of which deliver the blast side by side into one tuyere. There is thus at every stroke a very considerable abstraction of air from the blast.

India, in the region of the Himalayas. And it is certain that its original source is for the present beyond the range of investigation.

All Upper Assam is in fact girded by a broad zone of rocks, the Sub-Himalayan Series, from which, unless experience elsewhere, and appearances here, deceive us, very little is to be expected. Beyond this zone, any thing, unless of the most precious kind, must be out of reach of profitable extraction, besides being at present beyond our grasp.

The pungs.

The word *pung* means, I am told, a spring; but it is applied to places where this sense is not clearly applicable. The most general signification of the term is, a spot to which wild animals resort for some purpose best known to themselves, apparently to obtain substances having medicinal virtue. In the northern hills, on the Deijmoo and the Borgung, the pungs shown to me were mere salt-licks, bare surfaces of the soft Sub-Himalayan rocks, on which alternations of sun and moisture develop a faint efflorescence. The greater number of the pungs occur on or about the outcrop of the coal-measures. In some, as that 8 miles east of Jaipoor, the only thing to be detected is the slightly sulphuretted mud derived from the decomposition of the shales, or the slightly chalybeate water oozing from the same. In some, as that at Gabaroo (which is on an anticlinal axis of Sub-Himalayan rocks), there is a small discharge of mineral water with some gas. At the Namchik there is little water discharged, but more gas and a little petroleum. On the Makoom River there is a very copious discharge of inflammable gas with more of petroleum. The Namba pung has a very large flow of water, nearly at scalding temperature, and also much gas, both being sulphuretted. This spring occurs close to crystalline rocks, over which there seems to be but a thin covering of sandstone and limestone. The only saline spring I saw was near Asaloo; it seems to be on the same geological line with others in the Naga Hills to the north-east, in the upper valley of the Namchik, and intermediately.

Salt and petroleum.

Some of these springs, especially that at the Namba, might, I should think, be made use of medicinally; but the salt and petroleum might become important articles of commerce if obtainable in any quantity. Regarding the salt I cannot venture to make any suggestion; the pung near Asaloo is the only one I have seen; it is a small stagnant pool of brine, the mouth of a former shallow pit, at the very bottom of a valley; the whole is so smothered in jungle that I could not observe the rock anywhere near; the position is within a great band of disturbance (the continuation of that along the scarp of the Cossya Hills at Teriaghat), and the rocks seem to be of the Sub-Himalayan period. The position of these springs in the very heart of the hills almost precludes the possibility of their being worked profitably to any extent. The petroleum is, I think, worthy of attention. The springs of the Makoom River are far the most abundant that I have seen, but even here the discharge of petroleum is inconsiderable; producing a thin film on the surface of the stagnant pool of dirty, white water; this is occasionally skimmed off by the natives; but everything is in a state of nature; no excavation seems ever to have been made to facilitate the discharge of the oil. The locality is in a small drainage depression; the whole ground, over an area of many yards square, exhales olefiant gases; in the pools, which occur approximately along an east-south-east line, the discharge of gas is so copious and continuous that when lighted it flames almost without intermission. Of water-discharge there may be said to be none. Both these conditions are considered favorable; the abundance of gas suggesting that the reservoir of liquid (if such there be) has not been tapped; the little that does come is no more than would be caught up by the bubbling gas. On the other hand, where there is a discharge of water, it is a fair sign that the oil has run off. Two or three experimental wells or borings would, I think, be warranted to test these springs; but the very disturbed condition of the rocks will necessitate knowledge and caution on the part of those who undertake the work.

[redacted]

Geological Notes on Assam *and the Hills to South of* .

A season's excursion over a great part of Assam could scarcely fail to yield some results of general geological interest. Had such a general survey been the primary object of my visit, much more than I can show might have been made of it; but not knowing how much I should have to go through in examining the many coal-localities reported to exist, and which were the special subject in hand, I nowhere turned aside to investigate more general questions.

Age of coal rocks.

Although direct observation was sufficient to satisfy me of the extent and value of the coal-measures on the south of the valley, it was of much interest to arrive at some general opinion regarding their geological age. In the absence of fossil evidence in such distant sections, this object could only be clearly effected by tracing the rocks into connection with others that were known. For this purpose the Cossyah Hills afforded the required standard. I therefore ran an intermediate section across the whole range by the Kopili and Asaloo to Cachar, concluding the season's work by an eight-day trip in the Cossyah Hills. It is indeed to be hoped that we shall yet have a good collection of fossils from the coal rocks of Assam. The very limited search I was able to make cannot be taken as settling their character for barrenness. The shales, which are so largely developed, are full of plant remains, yet I obtained none that could possibly be identified. It is true that I had found the coal rocks, at least those of Jaipore, in contact with rocks so familiar to me as those of the Sub-Himalayan Series, and in the same intimate relation to them as are the nummulitic strata of Subathu in the North-Western Himalaya; but it would have been unpardonable to leave the question on so slender a footing when there was a chance of doing better. I will then commence by giving some little additional information regarding the geology to the Cossyah Hills.

Nummulitic and Cretaceous rocks at Cherrapoonjee.

The chief interest of the section at Cherrapoonjee, it will be recollected, rests upon the close superposition of undoubted nummulitic strata upon others containing a fossil fauna of which the facies is cretaceous; no stratigraphical boundary having been detected.*

It was of course an object to me, (and I may say I expected,) to find such a feature. I have, however, failed to do so positively. I can only help to clear the case for future more minute investigation. It is a peculiarly interesting one; not merely that there is no marked unconformability, but there are so many features common to the whole series of strata, it will be curious to find where, or whether, paleontology can draw an exact line. Unconformability of a kind can be shown: there is overlap. The many hundred feet of united thickness at Terria Ghât, at the outer edge of the range, is reduced at Mawbelurkar, some twenty miles to the north, to about sixty, all of which may probably belong to the upper or nummulitic group (see below page 37). Still every portion of the series of rocks now referred to undergoes this original thinning out; it is a condition of deposition common to all. Horizontal variation in kind as well as in amount of deposition is also common to the whole.

Trap of Cossyah Hills pre-cretaceous.

Trap rocks form a very remarkable feature in the geology of the Cossyah Hills. I have never seen, not even in Central India, such extensive phenomena of trappean intrusion. Aware of the important relations of the trap rocks in Western India with nummulitic and cretaceous deposits, as ascertained last year by Mr. W. T. Blanford, I sought some analogous conditions here, but without the same result. The trap of the Deccan rests upon cretaceous rocks, locally at least, and is older than, or partly cotemporaneous with, the nummulitic. All these strata just referred to as occurring at Cherrapoonjee are younger than the trap, a fact not

* See Quarterly Journal, Geological Society, London, Vol. XIX., p. 524.

without weight in the question of the age of these deposits, for it is at least *possible* that the trap rocks here are related to some of the great volcanic flows of India. This is the most positive addition I have to make to our knowledge of the region; some of these trap rocks having been hitherto supposed to be more recent even than the nummulitic group. The evidence is beyond doubt. Close to Mawbelurkar I obtained a clear cliff-section, showing the altered and disturbed conglomerates to be transversely overlaid by the conglomerates of the Cherra Series; the former belong to the Shillong group, the "secondary sandstones" of Mr. Oldham's description, and are seen to *sink into* the igneous rock, upon which the younger conglomerates here rest undisturbed.

The trap rocks have been observed in several positions, many miles apart. It is probable that some of these will be found connected, even at the surface, when the district is regularly surveyed; and it will be very interesting to trace their relationship, for they present very remarkable differences. From the Kalapani Valley to beyond Sohiong, trap occupies a great part of the section. It is, throughout, remarkably uniform,—a dense, basic trap more or less highly crystalline, spheroidal or sub-columnar. Ridges of several kinds of altered rocks are, as it were, buried in it, and are occasionally penetrated by veins from the main mass. In the trap so extensively exposed along the east flank of the Likenso outlier, at the edge of the range, the characters are altogether different. Here the common varieties are vesicular, amygdaloidal, earthy, compact, exceptionally sub-crystalline. In places there is distinct stratiform structure; partings of earthy, almost shaly, rock separating thick masses of harder varieties and assuming the general underlie in the region. I consider these to be truly stratified traps. I looked as closely as my time admitted for direct evidence of partial contemporaneity with the overlying sedimentary series, but unsuccessfully. The very marked prevalence in this position of dark green chloritic grains in the bottom beds of

Stratified trap.

the sedimentary strata, gives an apparent suggestion of some connection with the local subjacent rock. Some beds are almost entirely made up of such matter, and assume a spheroidal structure very like a trap rock. This may, however, be altogether deceptive. I did not observe any detrital matter in these rocks that could be *positively identified* as trappean.

Possible relation of the trap to the granite of Molim.

I would draw the attention of future observers to any connection that may exist between the central trap and the granite of Molim. I was greatly struck by the similarity of the relation of both to the quartzite sandstones of Shillong. At various points of the boundary from the south of Shillong, by Mawreng, to Lailangkot, the contact is very well defined. The coarsely crystalline granite comes close up to the stratified rocks, which are not *markedly* more altered than elsewhere, whether in a schistose form or as quartzite, both granular and compact. The beds observe no regularity, dipping to and from the granite at moderate angles, or abutting obliquely against it. About the centre of the granite area, south of Molim, I noticed some fine-grained, and even some sub-compact, trappoid masses. At a short distance west of Lailangkot the dense trap occurs in force within a quarter of a mile of the granite. I had not time to follow it up.

Considering the great development of trap in the Cossyah Hills, it would seem remarkable that no sign of such a rock occurs in the section across the same range in North Cachar. The fact is in accordance with the view here adopted regarding the age of this rock; the whole range is there formed by cretaceous and tertiary formations. I may also notice that I did not meet with trappean rock anywhere in Assam, unless as boulders in the great Himalayan torrents.

Other subjacent rocks.

In the *two* sections we have noticed at Mawbelurkar and Terria, trap has been seen as the chief underlying rock; and from the fact that in one locality at least it is stratified, one might suppose that its underlying the other rocks

was a general case. Such, however, is very far from being the fact. Below the station of Cherra other rocks are exposed in complicated variety beneath the cretaceous deposits. In descending into the deep eastern valley by the principal path from the native village of Cherra, a fine-grained granite, a conglomeratic schist, a hornblende-schist, are found in the undercliff; about the bottom a trap is seen exactly like that of the Kalapani. Coarse, clear, porphyritic granite also occurs. On the path leading up from the same valley to the Cutcherry, at the station of Cherra further to the south, a green, subschistose quartzite is almost the only rock seen. The sections are too covered to show the relations of these subjacent rocks. The elevation of the junction here, as well as the locality itself, is between that of the other two positions in which the contact is described.

Bottom rocks of the Cherra series.

The whole stratified series at Cherra may for convenience of description* be divided into three groups, locally well marked by physical features. The bottom-group varies much in kind and in thickness. In the section under Cherra station a massive conglomerate is conspicuous. It is coarsest at its base, passing up into the sandstone of which it is but a modification—a porous, coarsish, quartzose, non-micaceous rock, of pale yellowish and brownish tints according to the condition of the felspathic earth it contains; it is closely of the same character as all the overlying sandstones. In these sections chloritic grains are quite exceptional throughout the whole series; I only noticed them very locally in the conglomerate. Below Mawmluh to the west the bottom-rock is very much the same as at Cherra, perhaps less conglomeratic. Along the southern edge of the range, although the distance is but two or three miles, a great change is observed. The conglomerate is scarcely represented at all. When this rock exists it can scarcely fail to be seen in the debris, if not in section. On

* Oldham, Mem. Geological Survey, India, Vol. I., pp. 117—120.

the Terria Ghât I could only find a few blocks containing pebbles; and on the path over Wullong, three miles west of Terria, there seems to be none at all. In the latter section the trap shows close under a very thick mass of ochreous earthy sandstone, full of green chloritic matter; coarse angular grains of felspar and of granite occur through it in strings. All the bottom-group exposed on *Terria Ghât* is of the same description, and several hundred feet in thickness. In both positions, and probably more generally, it forms the scarp of the south face of the range; the overlying strata being weathered back from it. I look upon all this rock as the equivalent of the conglomerate and sandstone at the base of the sections at Cherra itself. The change in composition might, as I have suggested, be accounted for by the difference in the underlying rocks. The thickness varies locally, but there is a steady tendency to a rapid increase southwards.

Middle groups.

The next stage in our conventional grouping includes the rough sandstone forming the plateau of Cherrapoonjee with all between it and the bottom beds. The prominent rock is the yellowish sandstone, varying a good deal in texture, and containing more or less of earthy (felspathic) and calcareous admixture, fine grey earthy beds, shaly or nodular, alternate with the sandstone; they are very subordinate at Cherra, but are seen largely developed above the scarp at Terria Ghât. These beds also vary in composition, being sometimes calcareous, sometimes green with chloritic matter. The most remarkable case of rapid change that I noticed in this band was on the two sections already mentioned at Cherra, though only about half a mile apart; on the most northern path there are several beds of slightly sandy limestone, one very thick, just over the conglomeratic band; while on the southern path they are not to be seen, having probably merged into sandstone. It is principally in this stage that the cretaceous fossils have been found. The fossils are most abundant near the very base. On Terria Ghât they occur in a yellow, crumbling, sandy rock of very

irregular texture.* I noticed in it some of the large angular grains of felspar that are so largely distributed in the bottom-rock. Below Mawmluh a dark green, fragile rock is highly fossiliferous. In the inner gorges of the hills the sheer scarp is higher than along the outer range, and includes both the lower bands of strata. It would seem to be the great development of the middle shales along the southern zone that has caused the scarp there to terminate with the bottom-rocks.

Upper group.

The upper group also is physically well defined. It forms the well scarped hills rising from the plateau to the south-west of Cherra. It consists of fifty to eighty feet of pure limestone, covered by sandstones, shales, and coals, all being intimately associated. The top limit is a denuded surface. The variations in this band are as marked as in the preceding; the limestone and the coal are frequently wanting. These are the rocks definitely known as nummulitic. In seeking for a stratigraphical boundary corresponding to the change in the fossil fauna, one is naturally led away by the very marked physical feature at Cherrapoonjee. I could not find any sufficient confirmation of this suggestion. Unbroken sheets of the Cherra sandstone pass under the nummulitic rocks. Any irregularities that appear in it fall well within the natural conditions of deposition of such a rock. The sandstones above and below the limestone exhibit no characteristic difference, so that when the limestone is absent, this boundary would become imaginary; as north of Cherra, where the sandstones, with the coal, form part of the general scarp; the feature at Cherra being quite local. This question of a boundary seems to come to a crisis northwards; as at Mawbelurkar, ten miles from Cherra, where a rock apparently representing the very bottom of the whole series is associated with those of the topmost horizon; the total thickness being under one hundred feet, while on the outer sections it has been estimated as two

Crucial section at Mawbelurkar.

* Mem. Geological Survey, India, Vol. I., p. 118, &c.

thousand. If the conglomerate at Mawbelurkar be continuous with that in a corresponding position in the Cherrâ section, (as the coal there must, I suppose, be taken to represent the nummulitic coal,) I would almost despair of any traceable stratigraphical boundary being discoverable, and would look rather for a blending of the faunæ. I could see no pretext for separating the conglomerate at Mawbelurkar from the coal sandstone immediately associated with it. The only suggestion I can make to relieve the difficulty is, that the conglomerate of Mawbelurkar may not be the same as the conglomerate resting on the metamorphic rocks at Cherra. If this notion be correct, the much sought for boundary might be found by tracing the younger conglomerate into the Cherra section. A *possible* representative of it does occur there. The sandstone forming the plateau of Cherra station, though not different in kind from others above and below it, is the most massive band among the upper strata, and at or towards the base of it, on both the sections I examined below the station, I found it to be conglomeratic.

Hint of the desired boundary.

In connection with the suggestion I have just made regarding the stratigraphical demarcation of the nummulitic and the cretaceous strata, and with the relation of the trap to the strata of both periods, I considered the possible identity of the altered sandstone of Shillong and the conglomerate which so constantly accompanies it with the cretaceous rocks of Cherra. The lithological aspects are compatible, and perhaps even the conditions of disturbance. The less reconcilable features are, the distinct superposition of the Cherra beds to the stratified trap* of the southern sections, and the close proximity in the valley just below Cherra itself to the east of a trap like that of the Kalapani to the undisturbed and unaltered cretaceous rocks.

Possible identity of the Shillong rocks with the cretaceous.

* The connection of this 'stratified trap' with the more crystalline trappean rocks seen to the north has yet to be shown.—T. O.

[redacted]

Peculiar phenomenon of denudation.

While noticing the rocks of Cherrapoonjee, I would not omit a curious phenomenon of denudation which is there exhibited. It is the feature that strikes one most on first approaching the station, and it puzzled me for some time to find an explanation of it. The little rounded hillocks, whether isolated or in groups, scattered over the plateau of Cherra station, form a striking contrast to the prevailing scarped character of the main ridges. They are evidently, on the whole, homogeneous in composition and without any definite structure,—no partial scarp or projecting ridge betrays the presence of a continuous mass of rock in any definite position. On the road about Mawsmai these hillocks are cut at several places, showing them to be composed, to their very base, of a loose brecciated accumulation of broken rock materials, large angular blocks of sandstone in a base of more comminuted matter. At first I could see nothing for it but glacial action; I thought these hillocks must be remnants of moraines, although this opinion was a good deal shaken by my not being able to find any debris but that of rocks known to occur above the Cherra sandstone. I am now convinced that these little mounds are the result of a very different process of denudation, namely, the wholesale removal by the solvent action of subterranean water, of the band of nummulitic limestone which once covered this area. Mr. Oldham has described (p. 136) the actual operation of this process in the excavations of caves in the limestone of the plateau to south-west of Cherra, and in the falling in of large areas of the overlying rocks where the limestone had been thus removed. The present position of some of these rounded hillocks of broken rock away from the limestone scarp, and close to that of the great gorge, proves beyond a question in what manner the plateau of Cherra has been cleared. These little hills of broken material could not for a moment have resisted coast-action. It is but one more fact to the evidence that abounds in this region of the prodigious results accomplished by atmospheric action

during the lapse of incalculable time.* North of the station the rounded hills are confluent, and in the road-cuttings there all the intermediate stages of the phenomenon are seen; patches of the coal and shales are found crushed and contorted in a manner that it would be scarcely possible to account for in any other way, seeing that the underlying rocks are quite unbroken. It is probable that the limestone had never been as thick in this position as we now see it to the south. So very *exceptional a process of denudation* would be well worthy of mention in geological manuals. If *all* the limestone had been removed from here, as a large proportion of it has been, it would have been very puzzling indeed to account for the resulting appearances.

Structural features of the southern scarp.

From the descriptions already given, it will have been apparent that very marked stratigraphical conditions coincide with the orography of the Cossyah Hills. The undisturbed rocks to which the region owes many of its peculiar features were deposited upon and against a raised area having about the same general form as the actual range; they seem to be but the remnant of an overlap at the edge of a basin of deposition. Besides the very rapid thickening of the deposits to the southwards, there is from some distance north of Cherra a constant small inclination of all the strata in the same direction;† it may be due to original deposition. Additional conditions have, however, supervened to reproduce the ancient line of denudation. Coincident with the extreme southern limits of the table-land scarp in this position, there is a well marked axis of uniclinal flexure—an induced bend in the strata—whereby the top rocks are rapidly brought down to the level of the plains. It is of interest to fix correctly the nature of this feature of structure; for it is in marked contrast with others in apparently analogous orographical circumstances. Below the general run of the

* Mem. Geological Survey, India, Vol. I., p. 118, &c.

† Mem. Geological Survey, India, Vol. I., p. 120, &c.

scarp, and reaching to various heights, there is a narrow zone of low broken hills. In this ground the upper beds of the Cherra section are found in various states of disturbance; sometimes horizontal for a short space, sometimes locally much broken or contorted; occasionally so near the base of the scarp as to necessitate the supposition of faulting. As a rule they have a southerly dip;* and the successive stages of the series appear at their due distance from the axis of flexure, all being represented. Looking east by south from the scarp at Terria Ghât, there is an excellent view-section of what I consider to be the normal form of the feature. There seems to me to be nothing in these conditions to call for, or even to admit of the introduction of, any great feature of dislocation depending upon general causes. The induced phenomena of disturbance seem to link themselves most naturally to the original conditions of formation; the comparatively light accumulation upon a firm basis of crystalline rocks has escaped the crushing from settlement or otherwise, which has pervaded the deeper deposits beyond. As might be expected, it is in this part of the section that we find the youngest rocks of all. The denudation which in the western region has cut back nearly to the scarp of the horizontal rocks, appears to have been less and less effective to the eastward. At Burr Ghât Mr. Oldham observed that, "resting upon the low-lying limestone, there occurs a great thickness of sandstones of varying characters, with intercalated shales."† These are, in fact, the rocks which still more to the east form the Burrail (*great ridge*) range.

Distinctive structures of the hill regions.

A single name for the well defined hill-mass separating the plains of Sylhet and Cachar from the Bramahpootra Valley, is a decided want in geography, whether physical or simply topographical. Elsewhere, hills of far less magnitude and extent, and very much less defined in boundary, have long since

* Mem. Geological Survey, India, Vol. I., p. 167.

† Mem. Geological Survey, India, Vol. I., p. 138.

enjoyed a distinctive title; while these can only be spoken of in segments by the names of the local tribes—Garrows, Cossyahs, Jynteahs, Meekirs, Nagas, &c., &c.; there being no kind of natural demarcation between the several areas so designated. The proximity of the mighty Himalaya may perhaps account for this neglect. The more abstruse physical geographers may have been doubtful whether these hills might not belong to the Himalayan *system*; their position to some extent lends itself to this view, while simpler orographers may have looked upon them as a spur or continuation of the greater, but unknown, mountain region to the east. From the legitimate stand-point of physical geography, the latter is the correct aspect; as an uninterrupted hill-mass, influencing together the actual distribution of phenomena in this region of the earth's surface, the great western promontory can scarcely be separated from the mass with which it is continuous. In the endeavours, which are now so much in vogue, to popularize science, and in forced illustration of the correlation of all things, geology and geography have undergone a great deal of mutual inconvenience. The region under consideration seems to offer some very instructive evidence of how little actual geological observation confirms some too hasty speculations of the physico-geographer: we have here most extensive phenomena of disturbance, the resultant features of which seem due to the influences of local, I may almost say, superficial, secondary causes. And, on the other hand, these hills exemplify how entirely inadequate and unsuited the simpler considerations of superficial geography are for the requirements of geology; whether on the score of the age or the condition of the rocks, a large portion of this mountain area must be markedly separated from the rest; and it is not yet apparent how far either may be affiliated to the rock-phenomena of the Himalaya. The division here indicated is roughly marked by the valley of the Dunseeree. *To the west of this river we find, quite horizontal, some of the same strata which to the east are uniformly in a state of extreme disturbance.* Thus

The Shillong table-land.

the western hills might geologically be considered a table-land, though orographically they can scarcely be so regarded, denudation having operated so extensively that over the greater part of them there is not an acre of level ground to be seen. The tame, non-descript contour of this region may account for its having no single name throughout any considerable length. In the contiguous hills where the structure has led to the formation of high, peaked ridges, the names of Patkai in the north-east, and of Burrail in the south-west are applied throughout great distances to portions of the same range. As one must have a collective term for the western region, I will speak of it as the Shillong table-land, this being the name of the highest summit, and also the locality recently selected for the Head-Quarter station.

General rock-features of the table-land.

The general structure of the Shillong table-land is what has been described in the Cossyah District, locally more or less modified. Along the northern border granitic and gneissose metamorphic rocks occur continuously. The low hills which, singly or in groups, occur so frequently over Central and Lower Assam, especially south of the Bramahpootra, belong to the same series of rocks. Eastwards they terminate in the large group of the Meekir Hills; I know of no re-appearance of them beyond the Dunseeree. North of Gowhatty and Goalparra they stretch away towards the Himalaya. Westward the same rocks show obscurely on the right bank of the river at Doobric, striking into Cooch Behar. Thus a large part of the Assam Valley seems to have been excavated in this gneiss. At many places outliers of the horizontal rocks are found on the gneiss close to their northern border; but it would seem that this rock does not form the basis of the table-land generally. The quartzite sandstones of Shillong and trap have already figured largely in this position. There are also some very considerable masses of schists and of slates, some showing little or no signs of crystalline metamorphism. *Regarding all these rocks everything remains to be made out.*

Eastern section of the table-land.

I first came upon the rock conditions of the table-land in the extreme north-east corner of the area. A few miles south of Golaghât, close to the left hand of the Dunseeree, and almost at the level of the alluvial valley, the Namba stream has a fall of about ten feet over a low rib of gneiss. Within a few yards below the falls, and extending for some few score yards down the stream, there is a low rock section—thin bedded calcareous sandstones with partings of clay, and some compact limestone. All are very flatly waved, but so slightly as to indicate nothing positive. Having just come from the hills at no great distance to the east, where, throughout 150 miles, I had seen an enormous thickness of middle tertiary rocks greatly disturbed and forming lofty ridges, I not unreasonably set these beds down as something much more recent, possibly even sub-alluvial, though they differed greatly from the older valley-deposits, as usually seen. The fossils in the limestone are very obscure. Subsequent observation leaves scarcely any doubt with me that these beds of the Namba are cretaceous. I did not go further up the Dunseeree Valley, my route lay round the north flanks of the Meekir Hills. In crossing the table-land to Asaloo by the usual track from Nowgong, one first comes upon the overlying rocks at the falls of the Kopili. There is here a section remarkably like that noticed on the Namba. The most prominent rock at the falls is a rib of the very same gneiss, it being very easily recognized by its strange irregularity of texture, structure, and composition. The crystalline rock is here nearly covered by beds of fine hard sandstone. These stretch for some little distance below the falls in unbroken horizontal strata; and for some way up stream there is a succession of little falls and rapids over the same rocks; some slight waving is apparent, but in strong sandstones, with an irregular bottom-rock close by, this might be altogether a local, or even an original, feature. These actual bottom beds are here very fine and pure sandstones; at the contact with the gneiss they are much

compacted by siliceous infiltration or other chemical action to be expected in such a position. On the path through the low hills to the south we soon come upon beds of a different character, dark earthy, ferruginous, calcareous sandstones, very close representatives of the lower beds of the Cherra section. They are moreover pretty freely charged with fossils; and the few I brought with me have been recognized by Dr. Stoliczka as cretaceous forms, thus confirming the identification. The strata are quite horizontal and apparently of no great thickness; the hills being but low; and at one place, about ten miles south of the Kopili falls, where the path crosses the Chongun, this stream has cut about five feet into the underlying rocks. The strata thus exposed are the freshest looking of any I have seen in this position; finely laminated grey sandstones and dark bluish clays, without a trace of metamorphism; they are, however, vertical, with an east-west strike. The ferruginous sandstone here rests upon the disturbed rocks. The whole way to Goomaigoojoo, a most picturesque Naga village on top of a high hill, ten miles west of Asaloo, is over horizontal strata; sandstones, of sorts, greatly predominate; in fact none others are exposed. The total thickness of rocks cannot be much under 3,000 feet.

Position of the nummulitic band.

It can, however, confidently be presumed that other rocks exist, and would be discoverable by special search. The question is interesting with a view to the position of the nummulitic band. On this section through North Cachar I did not notice any beds that I could identify with the coal-rocks of Upper Assam on the one hand, or with the nummulitic rocks of Cherra on the other; I saw no sign of coal, limestone, carbonaceous shales, or of distinctive sandstone. I am disposed to infer, nevertheless, that a representative of some of those rocks does occur; the surface conditions here are very different from those in the Cossyah District; jungle prevails everywhere, and one may walk for miles without seeing rock in place. South and east of Goomaigoojoo the structural

features undergo a complete change. The rocks assume a high and constant dip towards the Burrail range. This is the actual continuation of the uniclinal flexure already noticed at the scarp south of Cherrapoonjee; and it would be natural to look here for the equivalent rocks of that section; but the evidence, both direct and indirect, is against this assumption. In this region the strata are much better exposed than where they are horizontal; in the deeply excavated longitudinal valley along the base of the Burrail range, and in the steep water-courses on its flanks, the rocks are well seen; yet no intelligence of either coal or limestone has been received, although both have been objects of enquiry to successive Civil Officers at Asaloo. The lime used at Asaloo is made from a tufa found in the gorges of the Burrail, at a considerable distance to the north-east, and possibly derived from some subordinate ingredient of the rocks. Evidence of this kind is by no means to be despised, especially in support of such flying observations as those I can bring forward. I believe the rocks of the Burrail to be the same as those of Goomaigoojoo; and all to be supra-nummulitic. The best affinity I can suggest for them is Sub-Himalayan. The type is certainly less well defined than in Upper Assam, but there is quite enough of it to make the supposition plausible. Judging from these general considerations, and from some features of the surface, I should be inclined to look for the coal-band along the north base of the Longlye ridge, about twenty miles south of the Kopili falls and five north of Waglai Village. The rusty fossiliferous cretaceous sandstones are only found to the north of Longlye. This ridge is the beginning of a considerable permanent rise in the general elevation, on which the rocks are of this quasi Sub-Himalayan character. Thus it would seem that over a large portion of the south-east corner of the table-land area we have much newer rocks than elsewhere, and showing, like others in this position, freedom from disturbance. There would be nothing new in the appearance of the nummulitic band well in on the table-land; and its complete concealment for a considerable space along

the line of flexure at the south limit of the area, by rocks which conformably overlie it, presents no difficulty, only giving us a larger measure of the action and re-action by which this feature was determined. If the suppositions I have made in this paragraph are correct, the bend northwards of the nummulitic outcrop must commence close to Moralli Poonjee, the extreme south-eastern point of Mr. Oldham's map, and where there is a note to the effect that "limestone is said to extend from this to the Assam Valley." I can only repeat that it and I did not meet on the road, nor yet in the Assam Valley.

Burrail range.

The double condition to which I have attributed the limitation of the region of disturbance is not so apparent in North Cachar as in the Cossyah District. The contorted and altered rocks forming the basis of the region I speak of as *table-land* have not been observed within many miles of the southern edge of this area; still their last appearance in the Chongun is higher than the contact at the Kopili falls, ten miles further north. The correlative features of a rapid thickening of the younger deposits beyond the table-land area can also be only conjecturally indicated at present. If all the rocks of the Burrail range, and of the deeply excavated valleys between it and the table-land, are of the same horizon as those forming the table-land, the question at issue can scarcely be raised. Three thousand feet, which is the most we are entitled to assume for the undisturbed rocks atGoomaigoojoo, would never satisfy the demands of the Burrail section. There can be no question that the actual strata of the table-land gradually assume the high easterly and southerly underlie; the massive sandstones are so seen in the gorge of the Diung to the south of Goomaigoojoo. The rocks out of which the longitudinal valleys have been excavated are, however, principally thin-bedded, sub-slaty shales: in the stream below Asaloo they are seen in considerable thickness without any sandstone. Similar beds, but very subordinate to the sandstones, occur in the Goo-

maigoojoo section. The most probable assumption is that the former are an expansion of the latter. The ridge of the Burrail is of massive sandstones of same type as those at Goomaigoojoo. In passing through this range, along the gorge of the Jatinga, one gets a good idea of the immense aggregate thickness of the rocks. The section seems to be an ascending one throughout. The dips are very high, and there is much local irregularity in direction, but the greatly prevailing underlie, both in the rocks of the longitudinal valley and of the range, is from the table-land area. I speak of the dip in this special way, because there is here a very marked change in the direction of the table-land boundary, of the Burrail range, and of the strike of the rocks, in which change all three agree in a remarkable manner; it is a point of special interest in the discussion of the phenomena of disturbance. Over Asaloo the Burrail range has a steady north-easterly direction. North of Cachar the diminution of the range being still inconsiderable, the direction is steady westwards, thus making a bend of 45°. The feature I have described along the inner base of the range, a system of longitudinal valleys—exhibits this curve most completely. The Jatinga, which flows southward through the range at the bend, bifurcates upwards on the north side into one of these valleys, the regular crescent shape of which is surprising when one considers the rough process by which its formation was determined; or, to speak more truly, this regularity bespeaks the quietness with which this process was conducted. The position of the transverse gorge is no doubt suggestive of a through break in the range; some such line of weakness did most likely exist, but the very tortuous course of the river forbids the supposition that there was any thing that could be called a fissure. The whole feature is rather indicative of bygone conditions of the surface,—that the primordial water-shed from which the actual drainage system was developed, was to the north of what is now the culminating line of elevation, and apparently on or about the axis of flexure. It would be

impossible from the very scanty data before us to conjecture how far the moving causes of the great rock disturbance I have described may have been external to, or independent of, the mass affected, or how far they may have resided in that mass. The two points I would insist upon are, the marked manner in which local conditions have influenced such vast rock movements, and the related fact of a great and sudden change of direction in one and the same great instance of disturbance.

Same rocks in the plains of Cachar.

I have said that the Burrail seems to be an ascending section from north to south. The outermost strata on this latter side are probably not represented at all beyond the ridge; they seemed to be the same as those forming the nucleus of the little hills and ridges, locally called *teelahs*, about Cachar. I saw some fresh cuttings in these rocks on the Sylhet and Cachar road near Kategurrah. There is much irregularity in composition and arrangement, both original and induced. Clear sandstones are associated in the most intricate manner, by oblique interlamination, with fine shaly clays, and all have undergone much irregular crushing. In the sandstones I noticed large blocks of silicified palm-wood, and well preserved impressions of leaves;* the clays also contain confused fossils. All these strata are probably of middle or upper tertiary age. The rock on which the little fort of Kategurrah is built is rather a puzzling one. On the river front it presents a most regular dome shape; the only divisional plains being those of rough concentric exfoliations; there are also minor spheroids within the mass, generally stained dark brown by iron; the texture and composition of the mass is equally undecided as to a mechanical origin; I considered for some time whether the whole might not be a deeply decomposed boss of fine granitic rock. It is most probably an extraordinary accumulation of the sandstone, which it resembles much in texture.

* These are all of dicotyledonous trees.—T.O.

Patkai range.

The north-easterly extension of the Burrail is the Patkai range of Upper Assam. I have only seen the very outer flanks of this on the skirts of the valley. In this position two groups of rocks can be roughly indicated—a great thickness of characteristic Sub-Himalayan strata, and the rocks associated with and forming the coal measures. The latter have been conjecturally identified as nummulitic upon the evidence of their close conformable relation to the lower Sub-Himalayan rocks, supported by the known occurrence of coal of this age in the Cossyah Hills. The direct resemblance between the groups at the two localities is not marked. The coal-sandstone at the Terap is a fair representative of the rock at Cherra, but shales predominate in the Assam measures, and the coal-seams are numerous and regular. It is by no means unlikely that some of the sandstones below the coal are cretaceous. In the preceding coal-report I have given some detailed observations of the sections in these regions. I need here only mention that the rocks are everywhere greatly disturbed, and that the almost universal underlie is southerly towards the Patkai ridge.

Sub-Himalaya.

From the information I received from Captain Godwin Austen just before starting for Assam, that on parts of the Bhootan frontier the crystalline rocks came to the edge of the plains, I was quite prepared to find Sub-Himalayan rocks wanting throughout Assam. I was therefore somewhat surprised to find them in full force throughout all the upper part of the valley. In the gorges of the hills north of Tezpoor and Dibroogurh one could not tell them from the Sivaliks of the North-West Himalaya—immensely thick strata of light grey sandstones, having a constant dip towards the main hills to the north. I could not penetrate any distance in these hills to see the extent of these rocks or their relation to those inside them. The really wild men, Akahs, Duphlas, Abors, Mishmies, &c., who inhabit these inaccessible ridges, are very much opposed to visitors, and

do not hesitate to maltreat them, even to the extent of decapitation. In the hills on the south of the valley, the flanking ridges of the Patkai range, these same sandstones are seen to have their usual capping of coarse conglomerates. I obtained a fossil elephant's tooth, found by Bryan Comber, Esq., in the gorge of the Deijmoo, north of Dibroogurh. These true Sub-Himalayan rocks extend for a considerable distance west of Tezpoor. They are easily recognized from the Bramahpootra forming a distinct flanking range to the higher mountains beyond; the white cliffs produced by the frequent slips on the south side of the wedge-like ridges betray these rocks from a distance. It would be very interesting indeed to ascertain whether the fact noted by Captain Godwin Austen is due to the removal of these rocks in that position by denudation, whether total or partial, a remnant being still left, though perhaps concealed by recent detritus; or whether it can be that they never existed there. This latter supposition receives considerable encouragement from the fact, already noticed, of the extension of low hills of gneiss from the Shillong table-land far to the north of Goalparra, towards the Himalaya. Indeed the significance of this latter fact cannot be nullified by the settlement of the question of a break in the Sub-Himalayan chain, apparent or real. The connection or relation of the crystalline rocks of Assam to those of the Himalaya would not be set aside by a thin intervening band of such sub-superficial rocks as these tertiary sandstones; and it promises to form a telling point in the discussion of mountain formation. The relation of the Shillong table-land to the Himalayan mass may not after all be imaginary; but it must be something very different from what is usually implied by the expression "mountain system." With independent reference to the question of disturbance, the very marked contrast in the behaviour of the same rocks to the Himalayan mass and to the table-land mass, is worthy of attention. In whatever degree the observation by Captain Godwin Austen comes to be confirmed, it is unique—from the Bramah Khoond

to the Indus I have heard of no other break in the Sub-Himalayan chain. It would seem most likely that these deposits on both sides of Upper Assam are continuous round the eastern extremity of the valley.

Alluvium.

I scarcely like to touch upon the very interesting and important, but most intricate, question of alluvium without having time or data to discuss it as it deserves. On first reading Mr. Ferguson's most valuable paper on the Delta of the Ganges,* it struck one as *primâ facie* anomalous, and requiring explanation, that the deposits of the Bramahpootra should be so backward as compared with those of the Ganges. Its volume is stated as equal to that of the Ganges, and the amount of silt it carries as immensely greater. The valley of Assam above Doobrie is insignificant compared to that of the Ganges above Rajmahal; over a large portion of it, moreover, rock seems to be near the surface. Yet the alluvial formation of Assam is far more backward than that of the Gangetic plains. Even supposing that most of the deeper deposits of the Dinagepoor region, and even of the Delta, were the work of the Bramahpootra, the actual relations of the rivers must have been long since established, and still the work of the Bramahpootra, in the Delta, which must to some extent precede that in its valley, is altogether in arrears as compared with that of the Ganges. The temporary diversion into the Sylhet Jheels would hardly be an adequate explanation. The difficulty for which I would seek an explanation is expressed by the question, why is it (remembering the silt-power of the Bramahpootra) that "at present the elevation of the river at Gowhatty, with 350 miles to run, is apparently lower than the Ganges at Rajmahal, within 250 miles of the ocean?"† Mr. Ferguson most correctly described Assam as in a "semi-habitable state." From the Bramah Khoond to Doobrie it is under the dominion of the waters. It is in the condition of a Delta without the power of vertical

* Quarterly Journal Geological Society, London, Vol. XIX., p. 321.

† Loc. cit., p. 330.

growth which a Delta must possess: the river has laid a deposit flush with its flood waters, as regulated by a fixed level of discharge below; improvement must begin from below by the raising of that fixed level. The question I have asked is, how that level comes to be so low as it is. As evidence of how these quasi-deltaic conditions obtain—how completely this stationary point of formation has been attained—I may notice a remarkable feature of the Deehing. This large stream drains the south-east terminal corner of the valley, as the Bramahpootra proper does that on the north-east. After leaving the gorge of the hills, it flows for several miles over a zone of *bhabur*, the flat slope formed by the coarser torrented debris. On about the middle of this slope, the river being still a strong torrent, it divides into two approximately equal streams; one flows tolerably direct to the Bramahpootra above Suddya, the other flows along the base of the southern hills through the rocky gorge of the Tippum range at Jyepoor and joins the Bramahpootra more than a hundred miles below Suddya. That a river should form itself into two (what in a delta are called *distributaries*) is necessary proof that it is constructing, not destroying; and that for many years such a bifurcation should be maintained, shows that there can be no choice of levels between the two courses.

Older alluvium.

Some slight modification has to be made to the conditions described in the Assam Valley. There are here and there patches of various extent that are raised a few inches over the highest present known flood level of the river; the so-called ridges of Tezpoor and of Bishnath are familiar localities of this kind, it is the ground most sought after for tea plantations. Although so little developed, these deposits are here the representatives of what has been called the "older alluvium," so extensively found in the Ganges Valley. It were of great importance that some definite opinion should be formed regarding these recent formations, as at present great doubt rests upon them, obstructing, if not vitiating, our speculations. It is still

a general opinion that this older alluvium is of marine formation. The more rational views of fluviatile rock formation, so uncompromisingly advocated by Colonel Greenwood,* and so graphically illustrated by Mr. Ferguson in the paper already quoted, are to a great extent adopted within the range of the actual river-courses; but these associated deposits are still looked upon as of a different order. The fact against their belonging to the actual form of conditions is, their higher raised position, apparently quite out of reach of the formative action of rain and rivers. They most commonly appear as a zone between the flat area of actual inundation and the hill-boundary of the plains, but they also show as islands of various extent in the plains. The most direct argument against the purely fluviatile formation of this older alluvium is its dissimilarity to the silt deposits of the delta or the river courses; its general character is a massive ochreous clay more or less sandy. Mr. Ferguson does not directly discuss this matter of the older alluvium; but in the only instance of it that comes under his notice, in the high ground north of Dacca (p. 329), he adopts unhesitatingly the same supposition; he identifies the rock with that found at Calcutta below the sea level, and he accounts for the elevation by special upheaval.

I do not at all gainsay the strength of these arguments; my opposition to them is rather an appeal than an argument, a protest against the use of extreme measures until the simpler ones have been fully tried. I think that the power of atmospheric causes to produce superficial deposits is altogether unappreciated. If the sea, or any water basin, is required for the production of a rock like this older alluvium, it seems to me that a very small part of India can escape submergence within recent times; I do not think this clay can be essentially distinguished from deposits occurring on all the table-lands of Hindustan. If this clay only occurred in what is its most characteristic position, along the border of

* "Rain and Rivers," 1857.

high ground, one might conjecture that it was purely a subaerial formation, by the "wash of rain," to use Colonel Greenwood's expression. But its appearance in the open plains implies some other possible mode of production. We do not yet know enough of the many conditions of river valley deposits to assert that it cannot have been formed by that process. And as for the fact of its isolation as a raised area surrounded by ground subject to inundation, such is a natural result of the process advocated by Mr. Ferguson, and without the aid of local or of *continental* upheaval. Were the case of the Madoopore jungle area an isolated one, it might be most reasonable to explain it as a special upheaval; but it would be inadmissible to make such a supposition for every similar case that might be cited. In the secular changes of a river during the process of raising its valley, it may cut away previously formed land, leaving portions of it for an indefinite time projecting high over the newly formed *khadur* (local river valley); or, the extensive destruction of a delta, whether by settlement, or by subsidence, or by a permanent change in the conditions of the receiving water basin, or even by some rare occurrence of oceanic violence, might so disturb the status of the river that it would have for a long period to prey upon previously formed deposits throughout the greater part of its valley; leaving portions of them as we now find the older alluvium in the valley of the Ganges. A very mild amount of such action would account for what I have described in Upper Assam; an erosion of a few feet in the river bed below Goalparra would have allowed of some permanent dry land appearing in the eastern districts. About Goalparra itself it seemed to me as if the hills alone were secure from flooding. The difference in kind between the old alluvium in Assam and the silt deposits of the actual river courses is even more striking than I have seen it elsewhere, although the origin of the former is most unmistakably not marine, but fluviatile (under the extensive meaning that must now be given to this word). The other deposits differ greatly on the opposite sides of the valley, as do also the sediments of the

rivers. Clear grey sand greatly predominates in the silt of the Bramahpootra, exactly like that composing the Sub-Himalayan sandstones. This character of the deposits from this great river is traceable too far down in the delta. In coming from Sylhet to Koostea the change on both sides is most marked between the brown earthy deposits of the Soorma and the Ganges, and the clear sandy sediments of the Bramahpootra. In the older alluvium on the north side of the Assam valley, the same may be observed; the high bank on which Suddya stands is a mass of partially consolidated sand, yet even here this dominant character does not completely exclude other influences; the high land of Bishnath and of Tezpoor is composed for the upper six or eight feet of strong ochreous sandy clay, resting on pebbly sand. On the south of the valley the sandy element is subordinate, but the deposits of the older alluvium are unlike the silt of the rivers. The section at Santok Mookh on the Dikhoo near Nazeerah will illustrate the whole case. At Santok Mookh the Dikhoo just overcuts the surface of a deposit of small boulders; all the stones, as in parallel positions in the rivers to the east, are of the fine hard lower Sevalik type of sandstone. The actual river deposit over this is chiefly a fine dark-grey sand, largely compounded of small slaty grains. The whole is in irregular beds of various thickness varying in colour and consistence with the proportion of clay, some layers being pure clay. At the base of this deposit there are many logs of wood not showing any signs of carbonization. A ferruginous ooze is common at the contact with the boulder bed. At the bend immediately below the Mookh a totally different deposit shows in the high right bank against which the river turns. The bottom, twenty feet or so, is a mass of stiff blue clay; several layers in it are shaly and largely carbonaceous. The small logs in this clay are highly carbonized, almost to the condition of lignite, hard, shiny black, fracture sharp, subconchoidal. The top of this clay is darker than the rest, and it is capped by eight feet of strong slightly ochreous unlaminated clay, the surface being four

feet above ordinary high water mark. The lower part of this section is apparently a jheel deposit. May not the top bed be some equally normal product of alluvium formation ? It is quite akin in appearance to what is called elsewhere old alluvium clay. It seemed to me that this top clay might even be a modification of the underlying bed by atmospheric and organic metamorphism.

It is to be hoped that some one who has more leisure than the members of the Geological Survey, and more opportunity of observing *repeatedly in the same district*, and of studying phenomena minutely, may arise to extend the researches so admirably begun by Mr. Ferguson.

O. T. Cutter, Military Orphan Press,—1865.

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I desire to take this public opportunity of correcting an error, into which I regret much I was led by a mistaken impression which I received in conversation. At page 198, I have stated that Mr. Rupert Jones had identified the Mangali crustaceans as *Estheria minuta*. This was not the fact, as appears more fully in Mr. Jones' own papers, subsequently published.

T. OLDHAM.

ERRATA.

It not unfrequently happens that these Memoirs are unavoidably printed during the absence of the writer, or of myself, from Calcutta, when the needful facilities for correcting the proofs cannot be secured. The reader is requested to make the following corrections :—

Page 14,	line 15	*for*	531	read	53.
32,	„ 17 & 25	„	Railyádi	„	Bailyádi.
45,	„ 29	„	this Report	„	the Report.
71,	last line	„	405	„	505
72,	first line				
75,	last line but one			„	Black carbonaceous Shales and Ironstones ... 20 *Lower Damúdas.*
86,	line 9	„	0 0	„	0 0½.
86,	„ 18	„	24 5	„	24 5½.
89,	„ 1	„	Dig uala	„	Dignala.
92,	„ 24	„	260	„	261
95,	„ 9	„	light	„	bright.
102,	„ 20	„	East 10°—20° West	„	East 10°—20° North.
106,	last line	„	W. N. W.	„	W. S. W.
118,	line 3	„	No	„	The.
119,	„ 20	„	Bara	„	Bora.
133,	„ 1	„	Rájmahál	„	Ránigánj.
137,	„ 7	„	unfossiliferous	„	fossiliferous.
142,	„ 27, 28, 29	„	where East occurs	„	West and *vice versa.*
148,	„ 6 from bottom	„	latter	„	later.
157,	„ 16 „	„	proprieters	„	proprietors.
165,	„ 8 „	„	finer	„	firmer.
172,	„ 16 „	„	5 to 6 pie	„	5 to 6 pice.
181,	„ 4 „	„	Gushik	„	Gushin.

On the map, a small isolated portion of 'Ránigánj' rocks, in the extreme east of the map, close to River Adjai, and between the villages of Samla and Bhonri, has been erroneously *coloured* as Lower Damuda.

Note relating to Sivalik Fauna.—*By* H. B. Medlicott.

(Read to Asiatic Society of Bengal, September 7, 1864.)

The notice I have to bring before the Society may be considered a continuation of a series of brief but important communications, commenced more than thirty years ago, and continued during some twenty years, as recorded in the volumes of the Journal of the Asiatic Society for that period. Those communications formed a current chronicle of the discovery of the *Fauna Sivalensis.* Had the account of those discoveries ever assumed a more connected and complete form, the correction I have now to make, would never have been needed, as it is but the statement of a fact, of which the evidence was in hand and in mind, although never expressed. Indeed, for the same reason, this fact can now be only indicated, its value being still unknown. This fact is—the existence of two vertebrate faunæ, possibly quite distinct, among the fossils hitherto collected from the so-called Sivalik rocks.

In a recently published number of the 'Memoirs of the Geological Survey of India', Vol. III. Part 2, I have given a somewhat detailed account of the geology of the Sub-Himalayan region in North-West India. I therein established a threefold division of the great series of deposits coming under the general title of Sub-Himalayan. Concerning the lowest of these groups (Subathu, etc.) little or no conflicting evidence presented itself. The two upper groups I described as in all respects more akin to each other, although still most clearly separable along a well marked boundary, at which the younger strata overlap the steeply denuded edges of the older, besides being largely made up of their debris. Such evidence is so immutable to the geologist, and, when on so grand a scale, entails such grave considerations of time, that I presumed to call in question the one published statement (in Vol. III. p. 527 of the J. A. S. B. for 1834) of vertebrate Sivalik fossils having been found within the area of the older groups,